

# HEP@Tsinghua University

## - An Introduction

Yuanning Gao  
Tsinghua University

# A brief history of physics@TU

- 1926 **Department of Physics established**, soon earned a reputation as one of the best Physics Departments in China
- 1952 **Became a polytechnic university**, Department of Physics dissolved and most faculty members and students joint Peking University
- 1956 **Department of Engineering physics** established for Chinese nuclear science
- 1982 **Department of Physics** re-established

# Department of Physics

Faculty: ~90

Undergraduate Students: ~400

Graduate Students: ~400

Research fields:

- Condense Matter Physics
- Atomic and Molecular Physics
- Astrophysics
- High Energy and Nuclear Physics
- ...

# Department of Engineering Physics

Faculty: ~120

Undergraduate Students: ~600

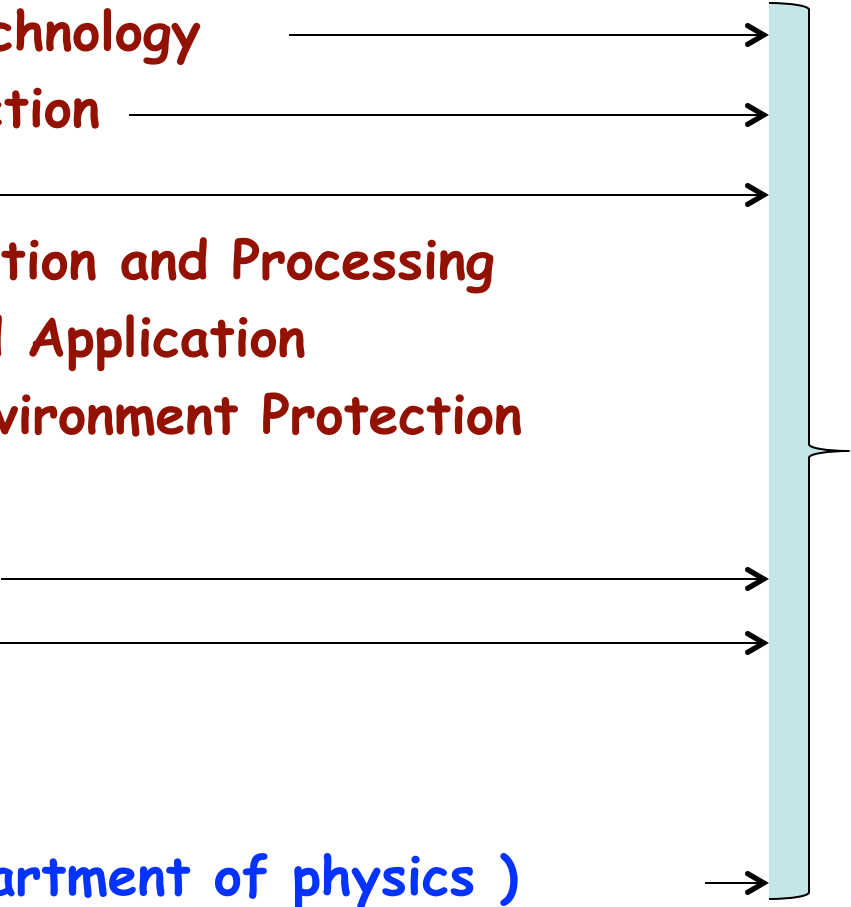
Graduate Students: ~600

Institutes: 6

- **Nuclear Technology** →
- Technical Physics
- Nuclear Energy Science and Engineering
- Medical Physics and Engineering
- Safety Science and Technology
- **Modern Physics** →



# Department of Engineering Physics

- Accelerator Physics and Technology
  - Radiation Physics and Detection
  - Nuclear Electronics
  - Particle Information Acquisition and Processing
  - Nuclear System Control and Application
  - Radiation Protection and Environment Protection
  - Particle physics experiment
  - Particle physics theory
  - Astrophysics experiment
  - Particle physics ( from Department of physics )
- 
- The diagram consists of a vertical light blue bar on the right side of the slide. A horizontal bracket is positioned to the right of the bar, spanning the height of the first six items in the list. Arrows point from the text of each item to the bar: the first six items have arrows pointing to the top of the bar, while the last three items have arrows pointing to the bottom of the bar.

# Center for High Energy Physics (TUHEP)

- A (virtual) organization
- Members from department of physics & department of engineering physics  
+ others (mechanics, computing ...)
- Director: Yuanning Gao
- Not all HEP projects are organized by the center

# Tsinghua Center for Astrophysics (THCA)

- A (virtual) organization
- Members from department of physics & department of engineering physics  
+ others
- Director: Charling Tao

# Center for High Energy Physics

- Theory group (4+1 faculty members)
- Experiment group (1+5 faculty members)
- Accelerator group
- Detector group
- Electronics group

Department of Physics  
Department of Engineering Physics

- Graduate students: ~20
- Postdocs: 6

**Welcome new members !**

# HEP Projects @TU

- China Jing Ping Underground Lab
- LHCb (EX+EG), BES (EX+EG)
- RHIC/STAR(EX+DR), CBM(TH+DR)
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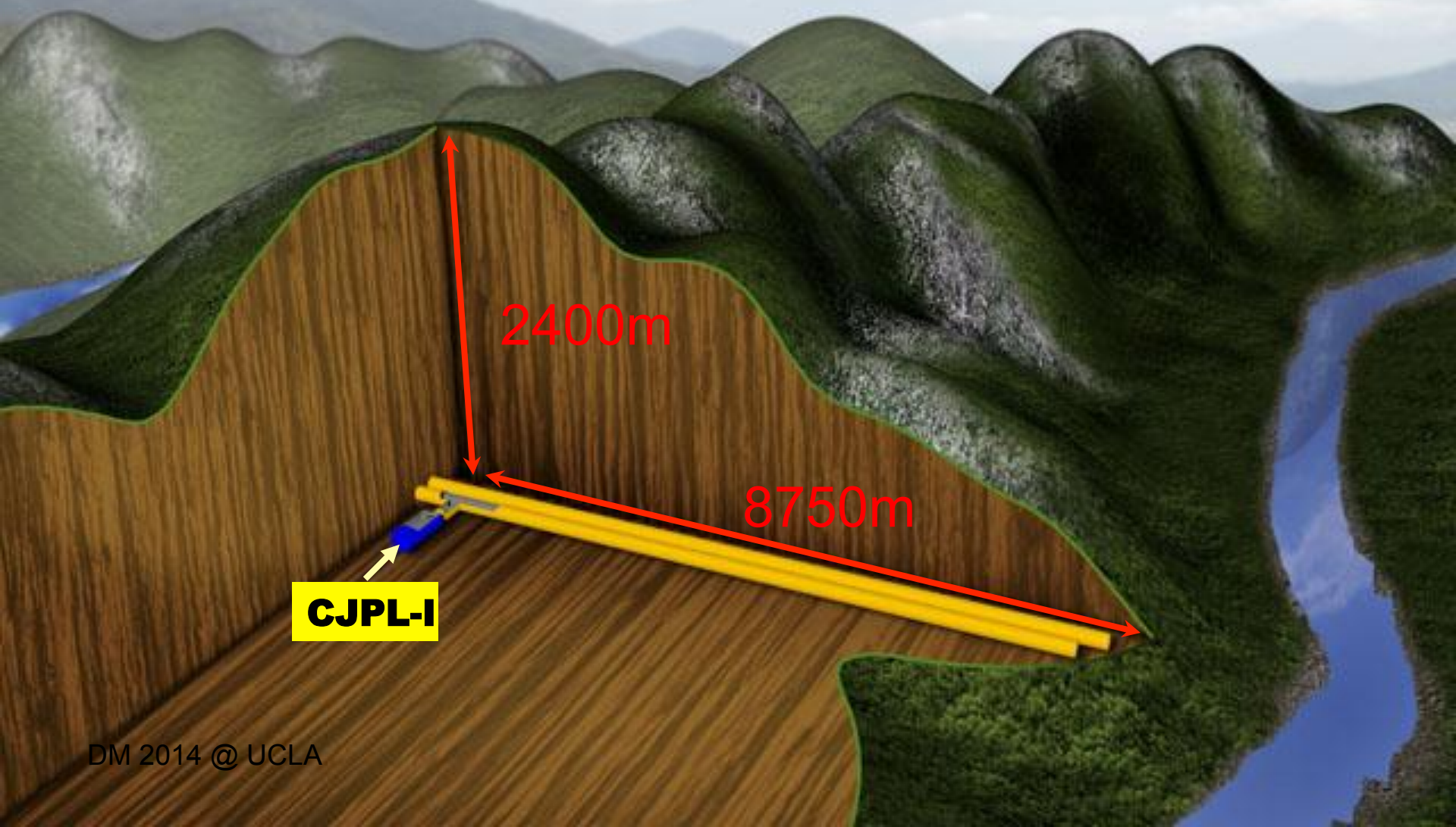
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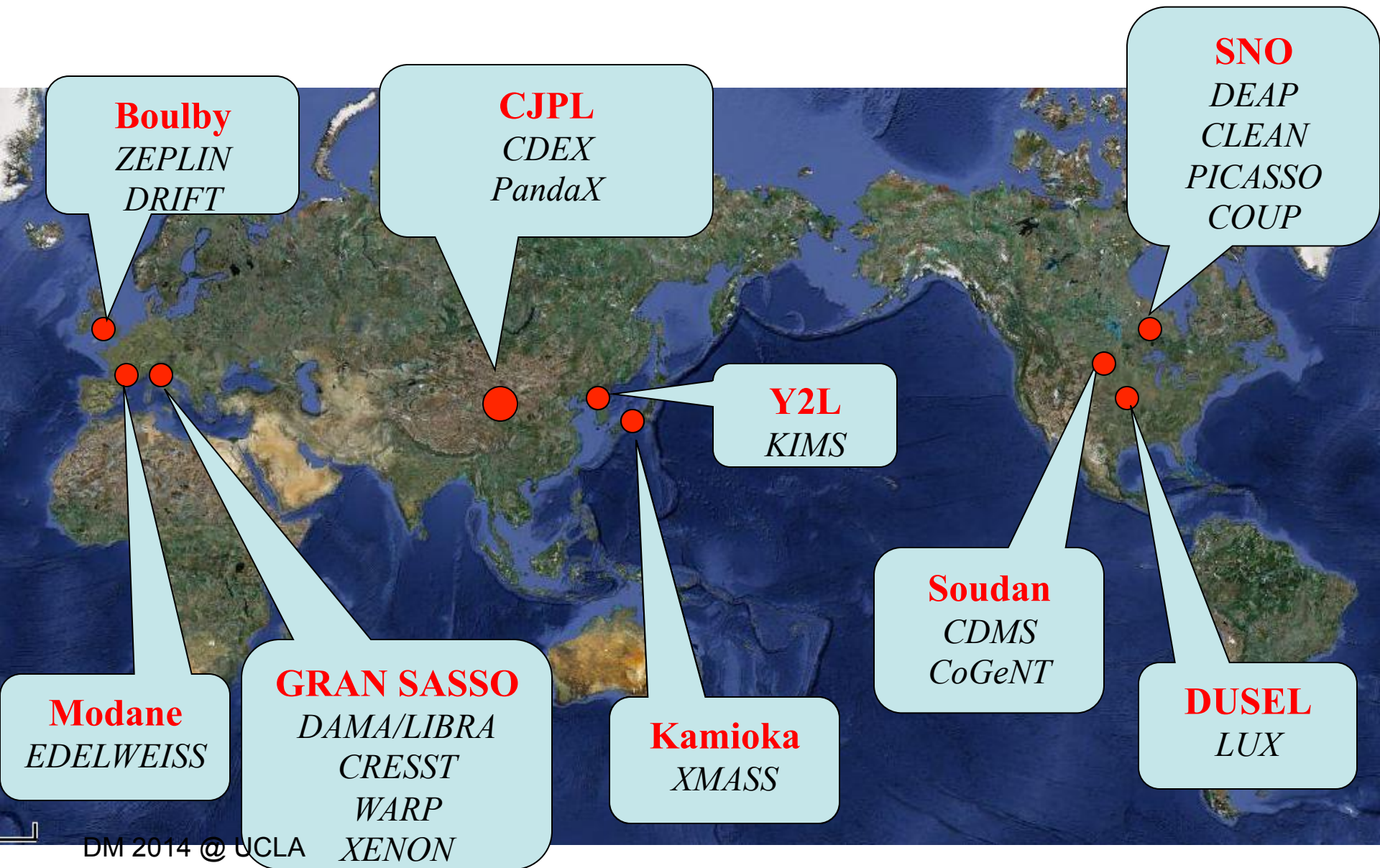
# China JinPing Underground Laboratory (CJPL)

Q.Yue's talk



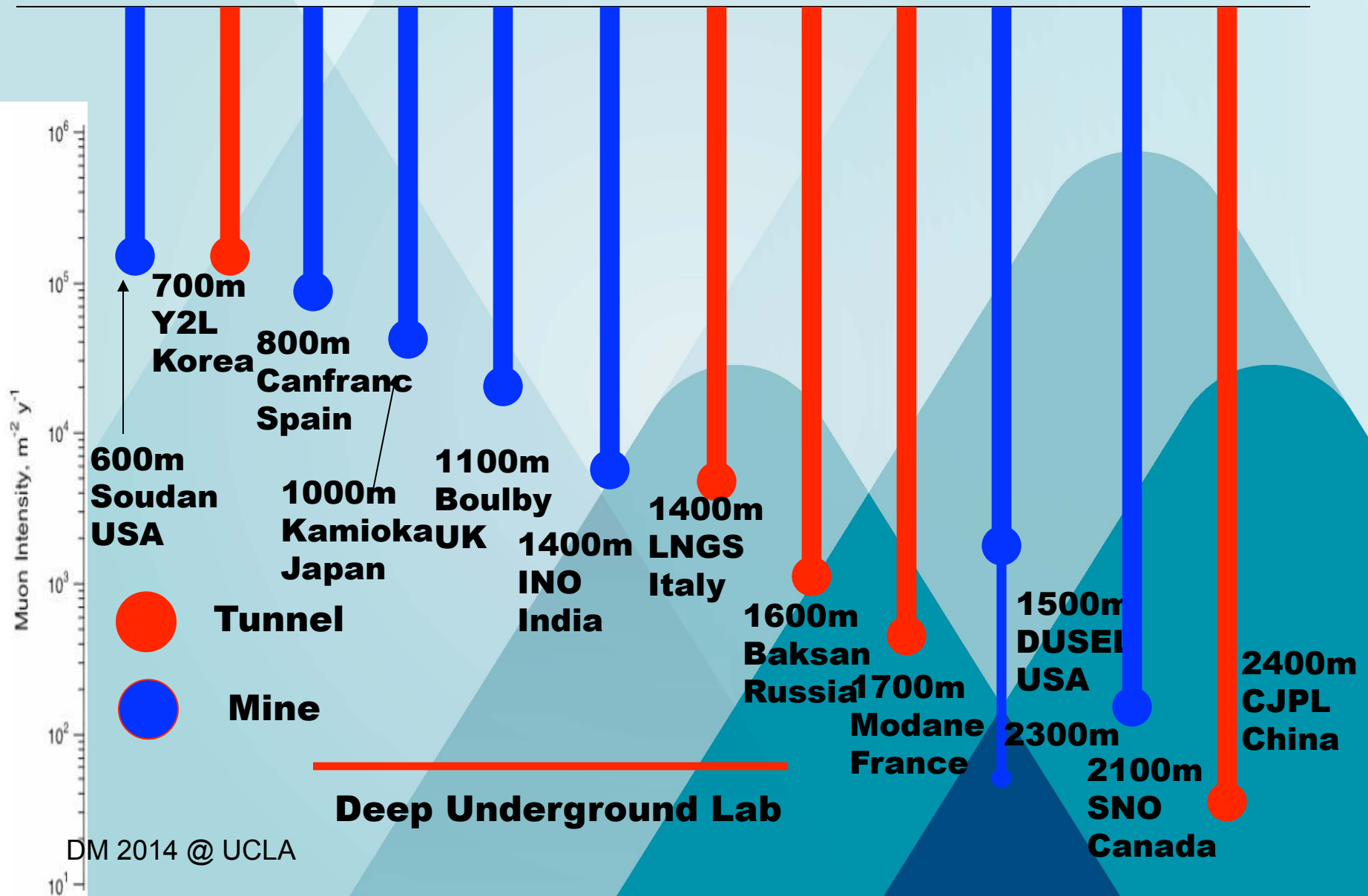


# International Main Underground Laboratories

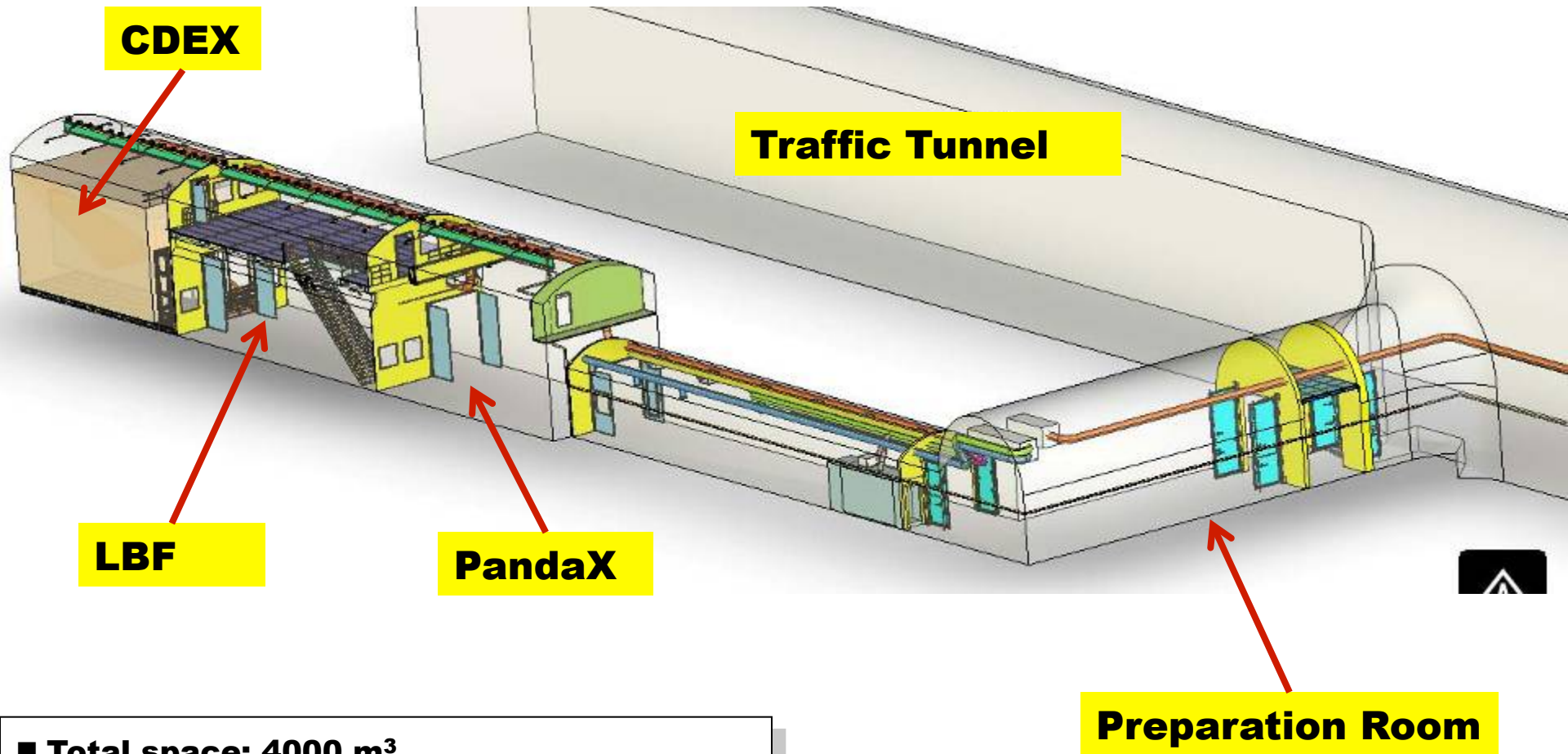




# UL in the world (rock overburden)

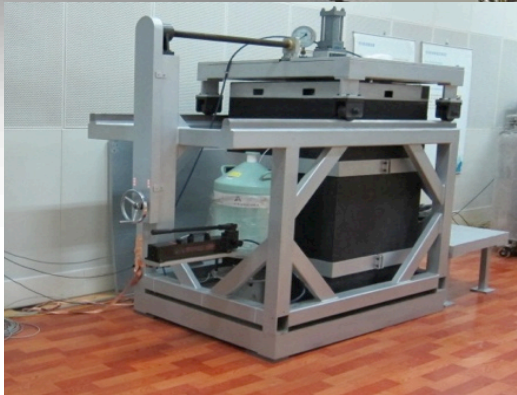


# Layout of CJPL-I



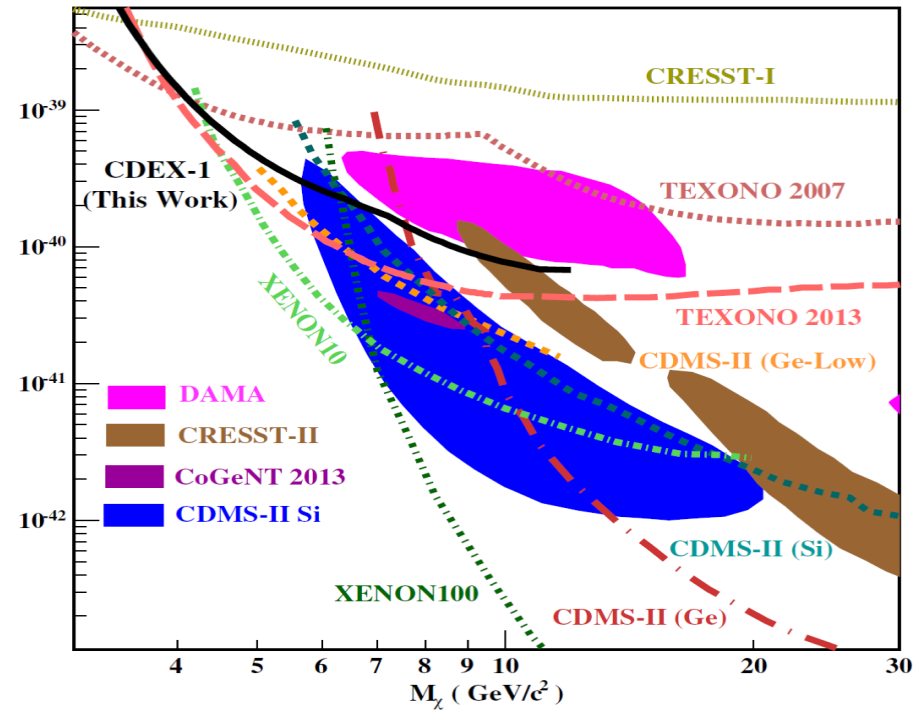
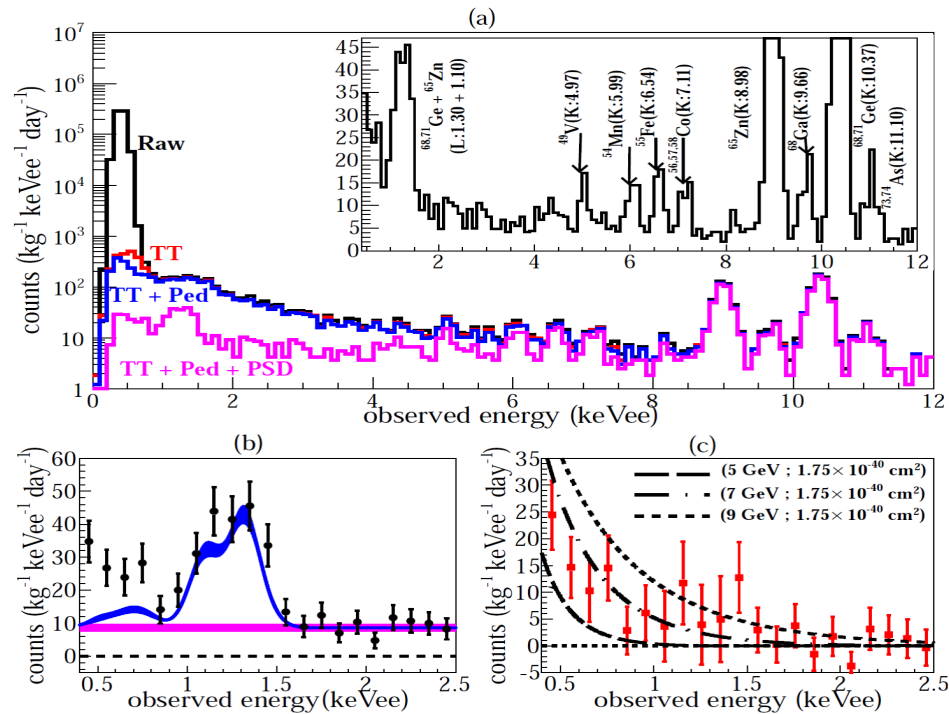
- Total space: 4000 m<sup>3</sup>
- Main Lab Space: 6.5(W) x 6.5(H) x 42(L)

# CJPL internal layout



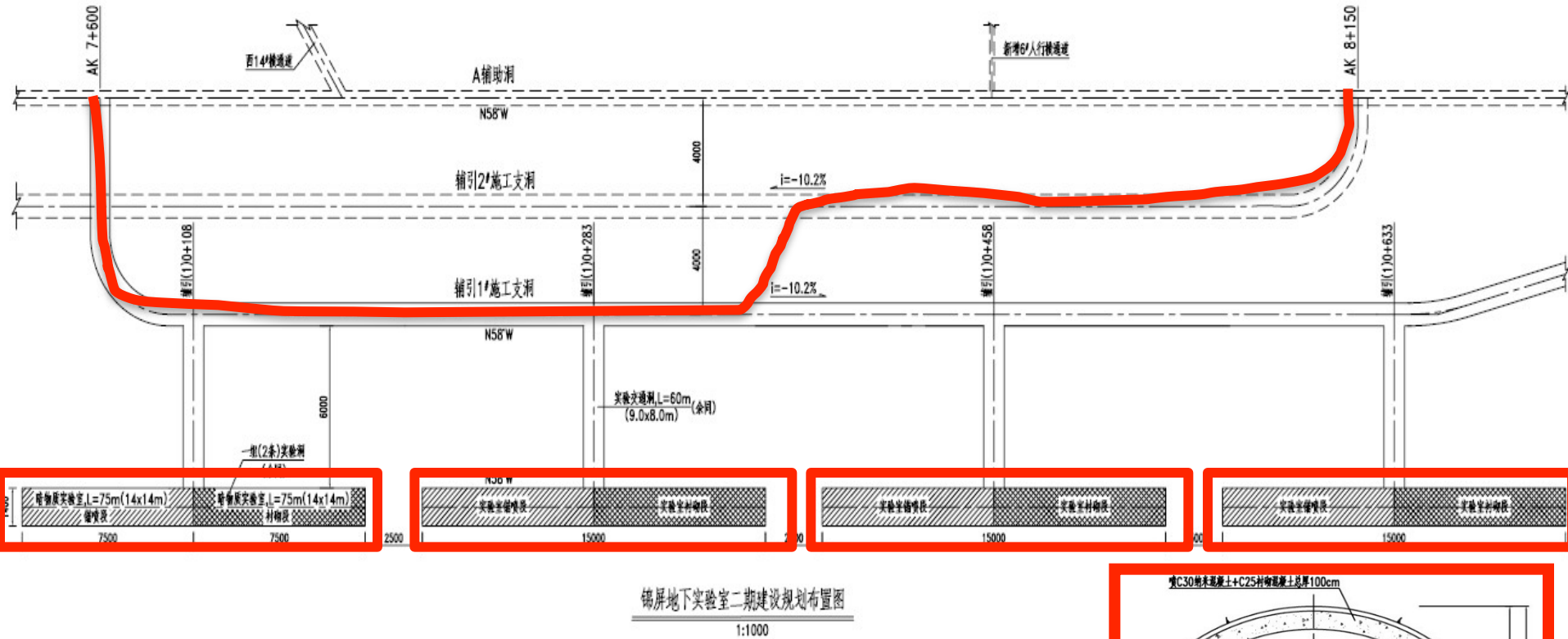


# The first CDEX-1 result



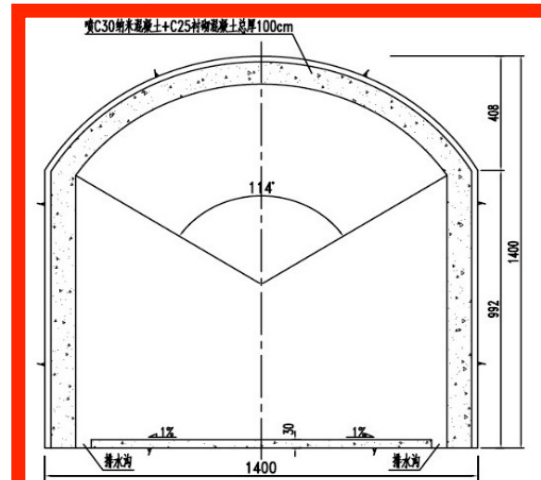
• PRD 88 (2013) 052004

# CJPL-II design



- Four 12m\*12m\*150m tunnel
- Plan to be finished in 2015

DM 2014 @ UCLA



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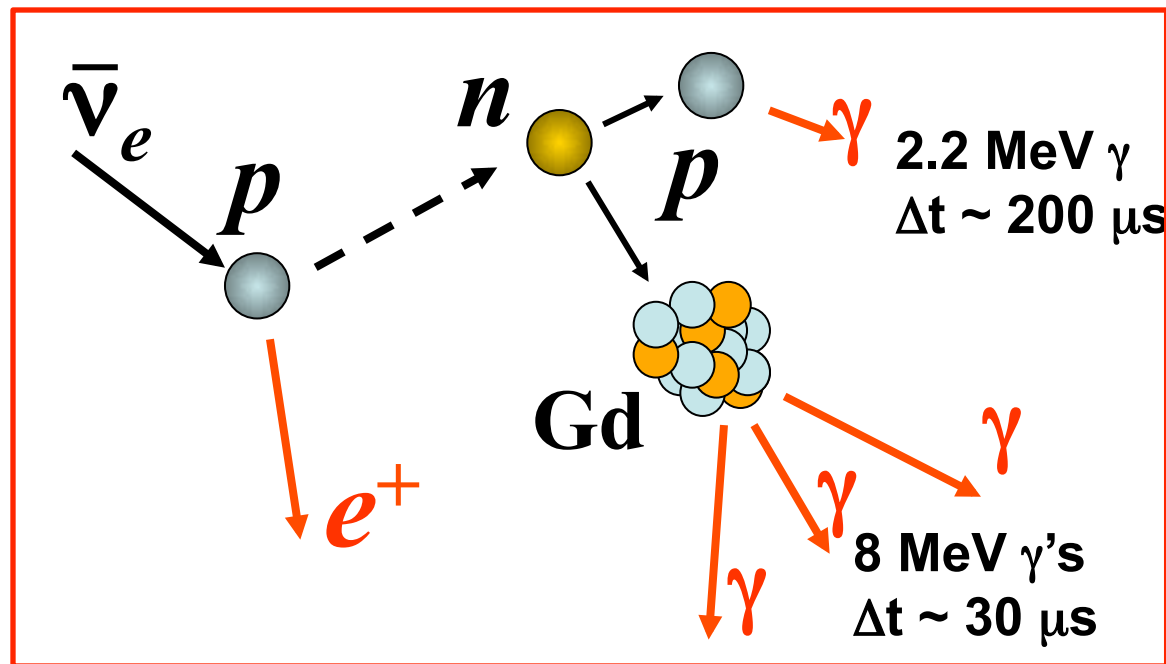
# Activities @LHCb

- **Physics**
  - Quarkonium production
  - Bc measurement
  - pA analysis
- \* Zhenwei Yang, subgroup convener
- Yiming Li, subgroup convener
- \* Successful collaboration with LAL  
(P. Robbe's talk)





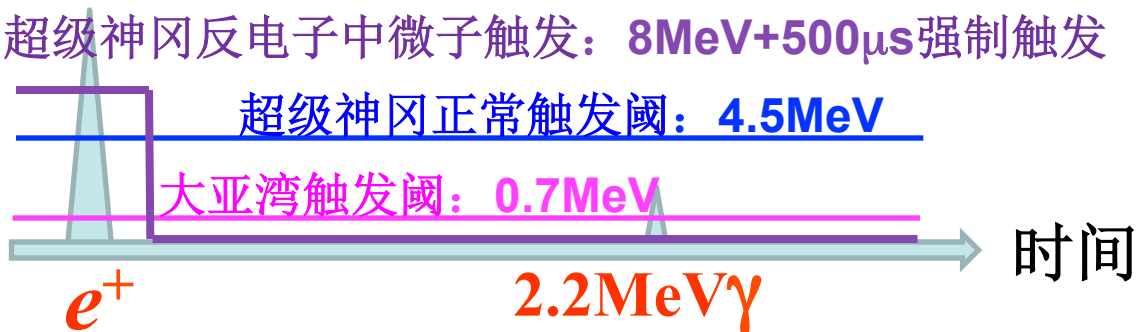
# 低能反电子中微子的识别



超级神冈反电子中微子触发:  $8\text{MeV}+500\mu\text{s}$ 强制触发

超级神冈正常触发阈:  $4.5\text{MeV}$

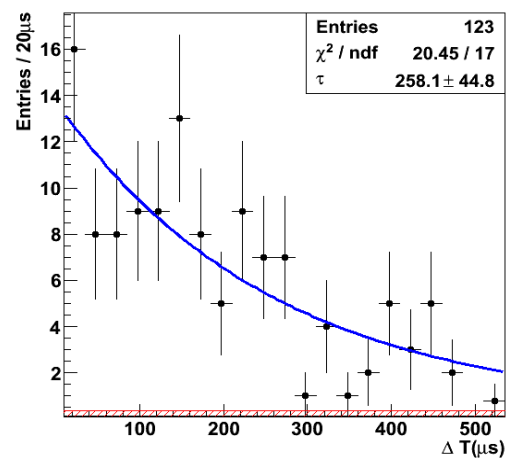
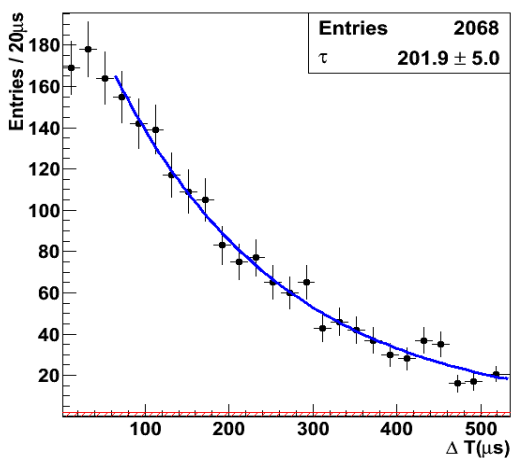
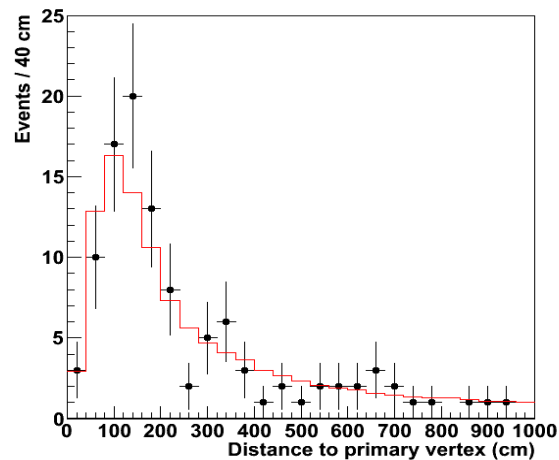
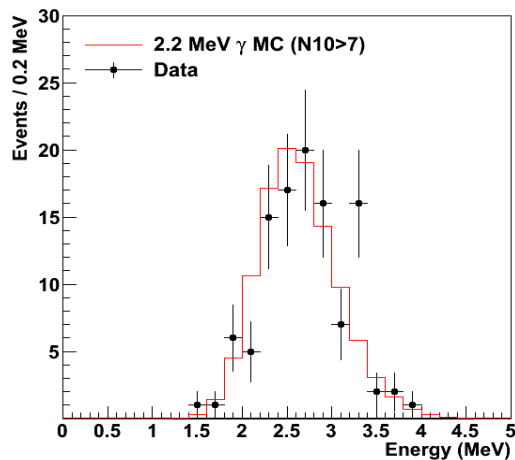
大亚湾触发阈:  $0.7\text{MeV}$



此项研究要解决:

1. 大亚湾液闪探测器本底高且复杂的数据分析问题
2. 超级神冈水质期伦科夫探测器信号幅度小的触发与数据分析问题

# 超级神冈实验反电子中微子识别



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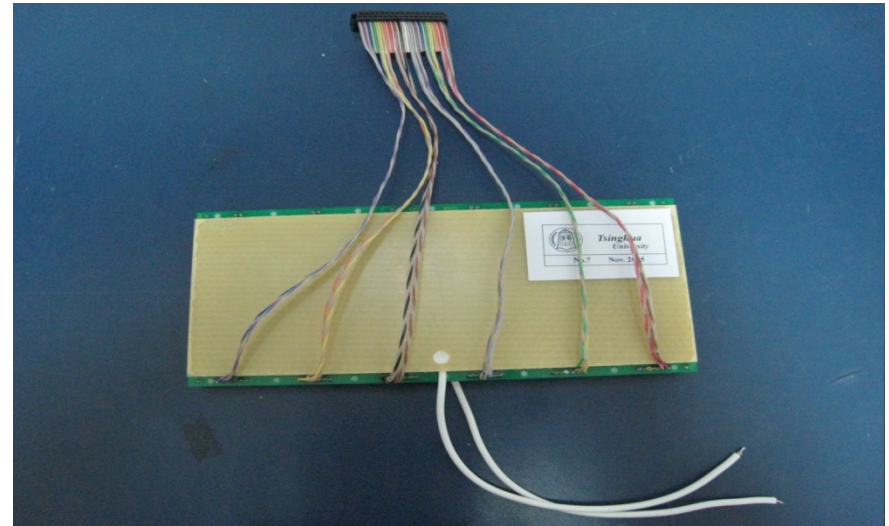
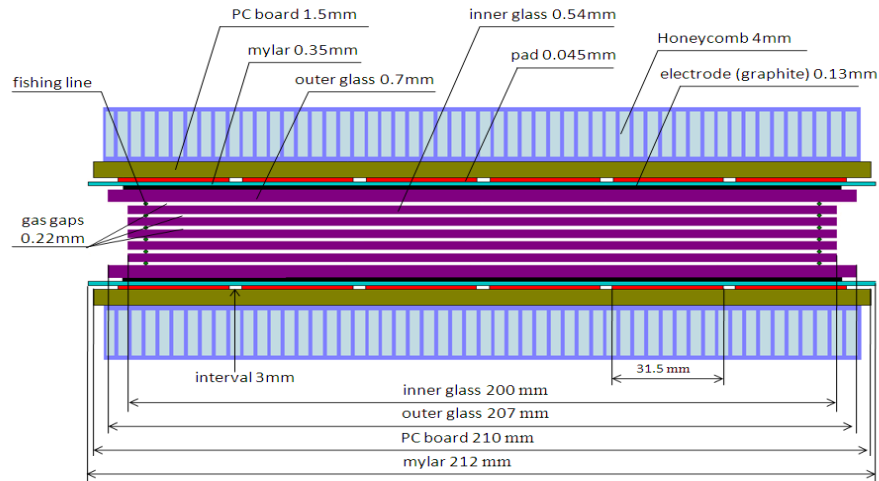
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# RHIC—STAR TOF MRPC



Glass:  $\sim 4 \times 10^{12} \Omega \cdot \text{cm}$

Carbon tape:  $100\text{k } \Omega/$

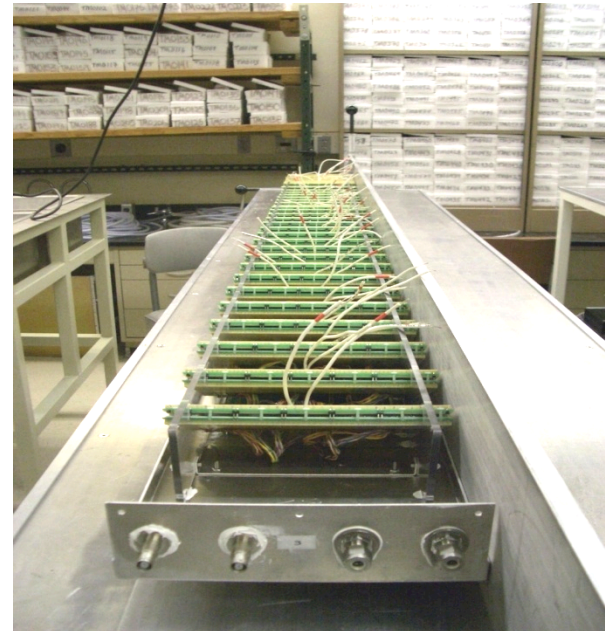
Gas gap:  $6 \times 0.22\text{mm}$

Working gas: 95% F134a+5% iso-butane

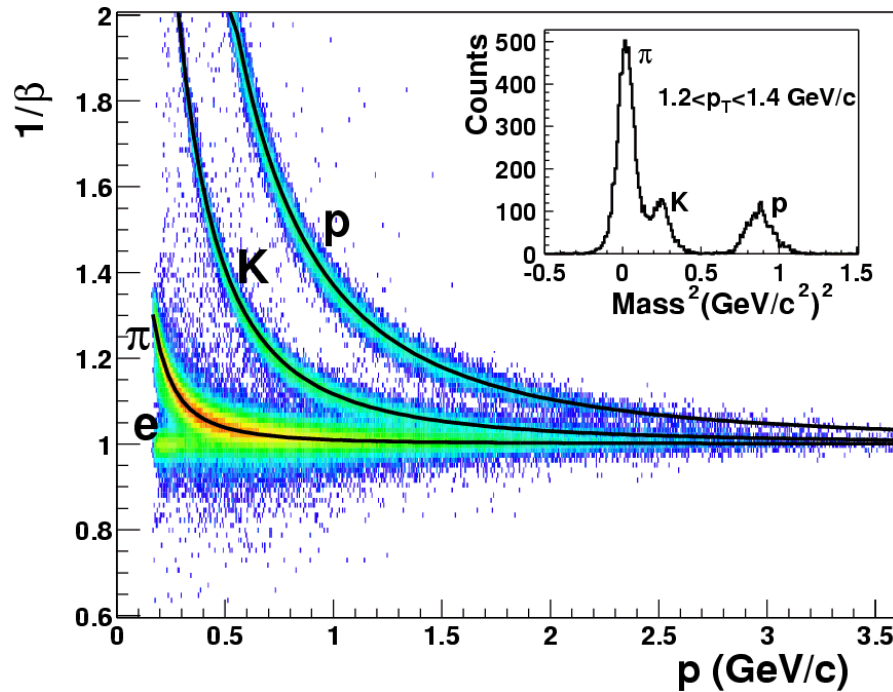
Time resolution: 80 ps

Efficiency >90%

**Rates capability:  $200\text{Hz}/\text{cm}^2$  !**



# PID and anti-Helium



PID of TOF:

$\pi / k \sim 1.6 \text{ GeV/c}$

$(\pi, k)/p \sim 3.0 \text{ GeV/c}$

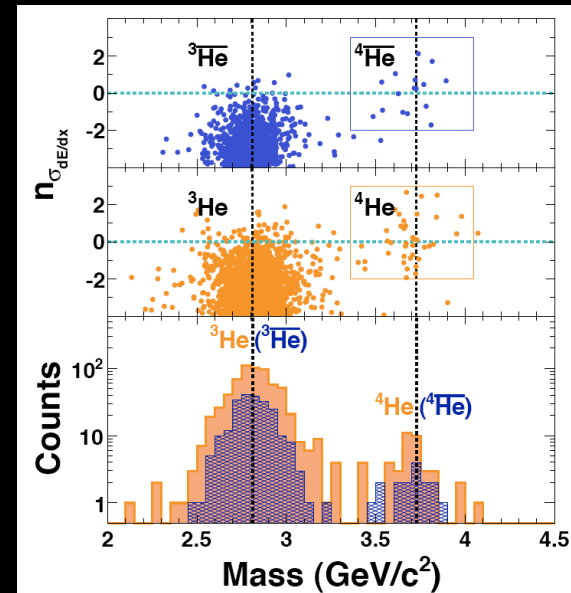
**nature**

April, 2011

**“Observation of the Antimatter Helium-4 Nucleus”**

*by STAR Collaboration*

*Nature, 473, 353(2011).*





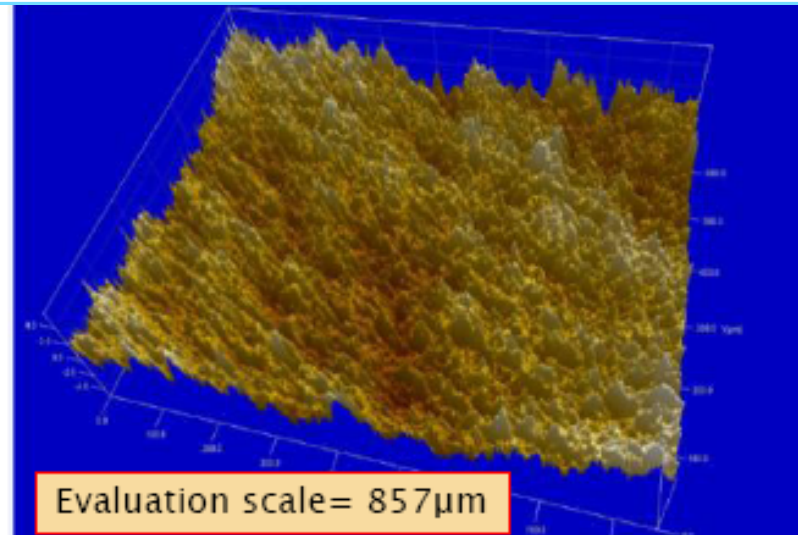
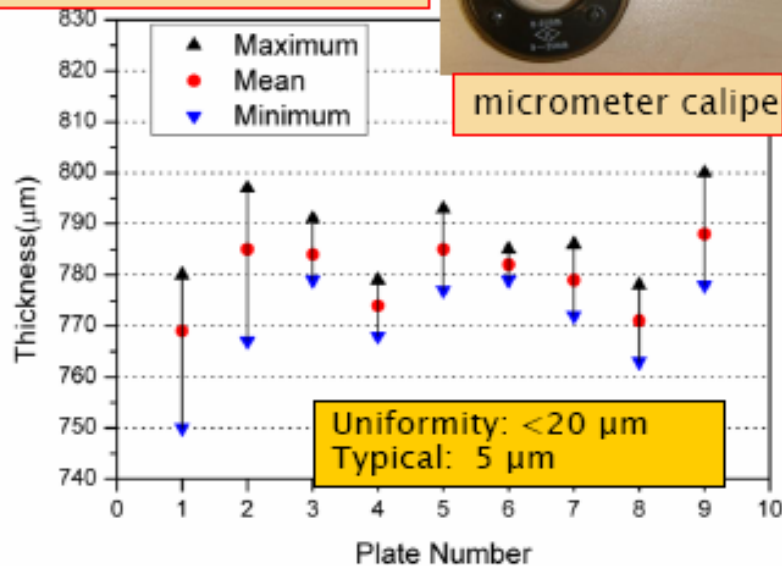
# Development of low resistive glass

32cm x 30cm

Thickness distribution  
(Evaluation scale= 30cm)

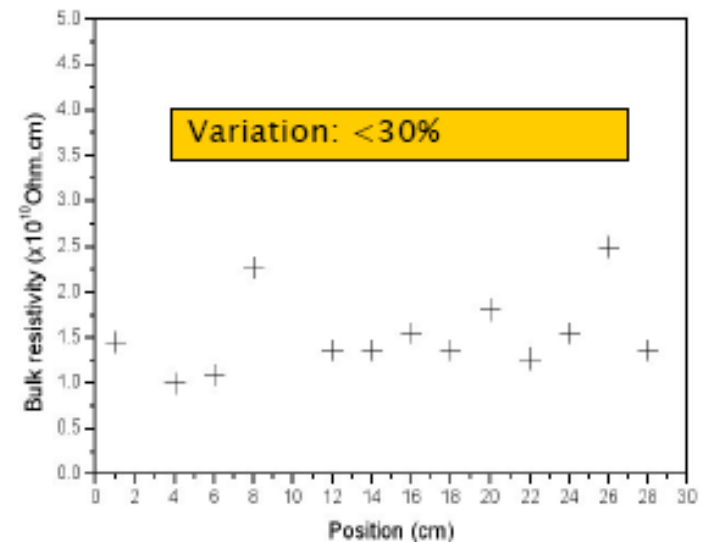


micrometer caliper



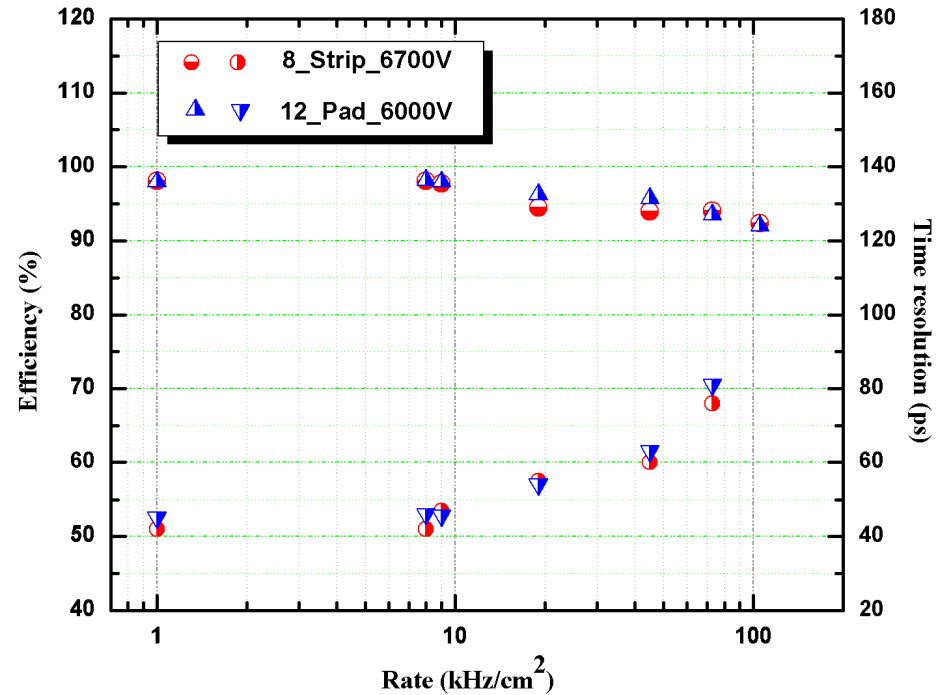
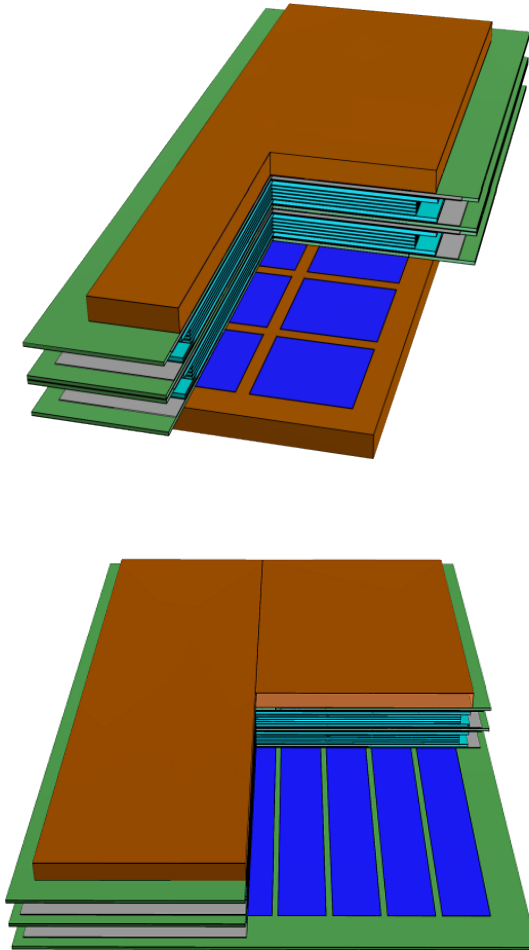
Evaluation scale=  $857\ \mu\text{m}$

Surface roughness:  $<10\ \text{nm}$  (peak-to-valley)

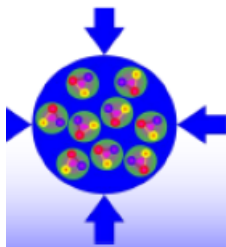




# Development of high rate MRPC



*Even though the rate is **70kHz/cm<sup>2</sup>**, the efficiency is still higher than **90%** and the time resolution is about **80ps**.*

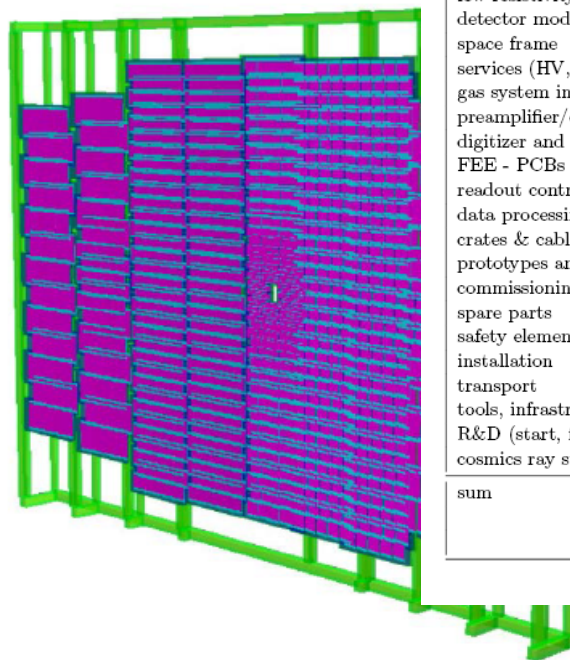


# Technical Design Report for the CBM

## Time – of – Flight System (TOF)

**High rate MRPC technology was adopted by CBM, China in kind contribution is 3M euros.**

### The CBM Collaboration

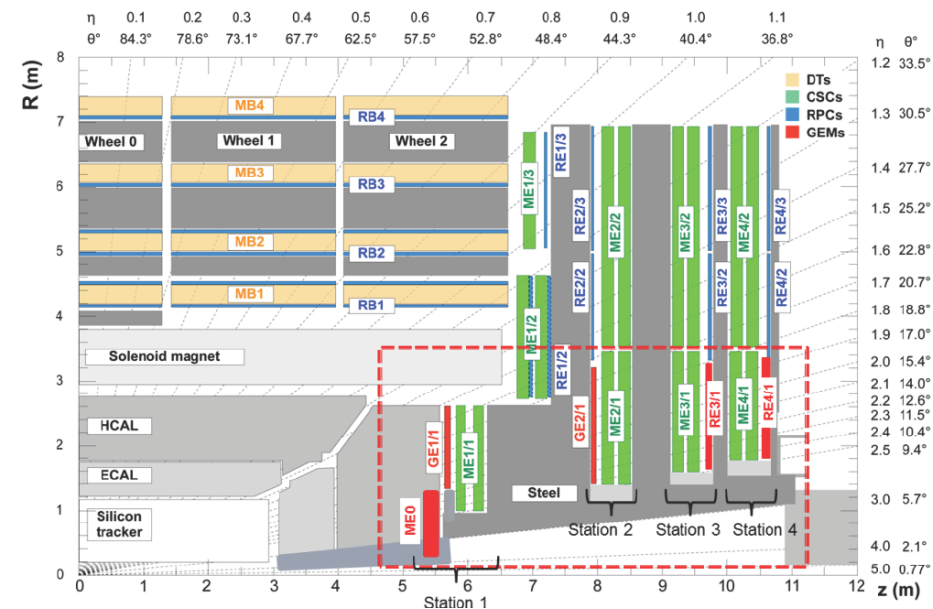


	THU,USTC,CCNU	GSI	HZDR	UHEL-PI	IFI	NIPNE	ITEP	cost [kEuro] in 2009 prices
low resistivity glass plates	1620							1620
detector modules	380		20			300	100	800
space frame						100	200	300
services (HV,LV,cooling)	100		200	50	50	50		450
gas system incl. controls				200				200
preamplifier/discriminator		100		150		100		350
digitizer and clock		600						600
FEE - PCBs	100			50				150
readout controller (ROC)				50	350			400
data processing board (DPB)	300			50				350
crates & cables	120					100	30	250
prototypes and tests	180		20					200
commissioning	20						30	50
spare parts	100		30			100	70	300
safety elements		50						50
installation		80						80
transport	30					20		50
tools, infrastructure	50		50			30		150
R&D (start, forward RPC)			180				70	230
cosmics ray stand				50				50
sum	3000	830	500	600	400	800	500	6630
			2330					
	China		Germany			Romania	Russia	total

Table C.2: Intended sharing of construction costs between the project participants.

# CMS collaboration

## CMS RPC upgrade

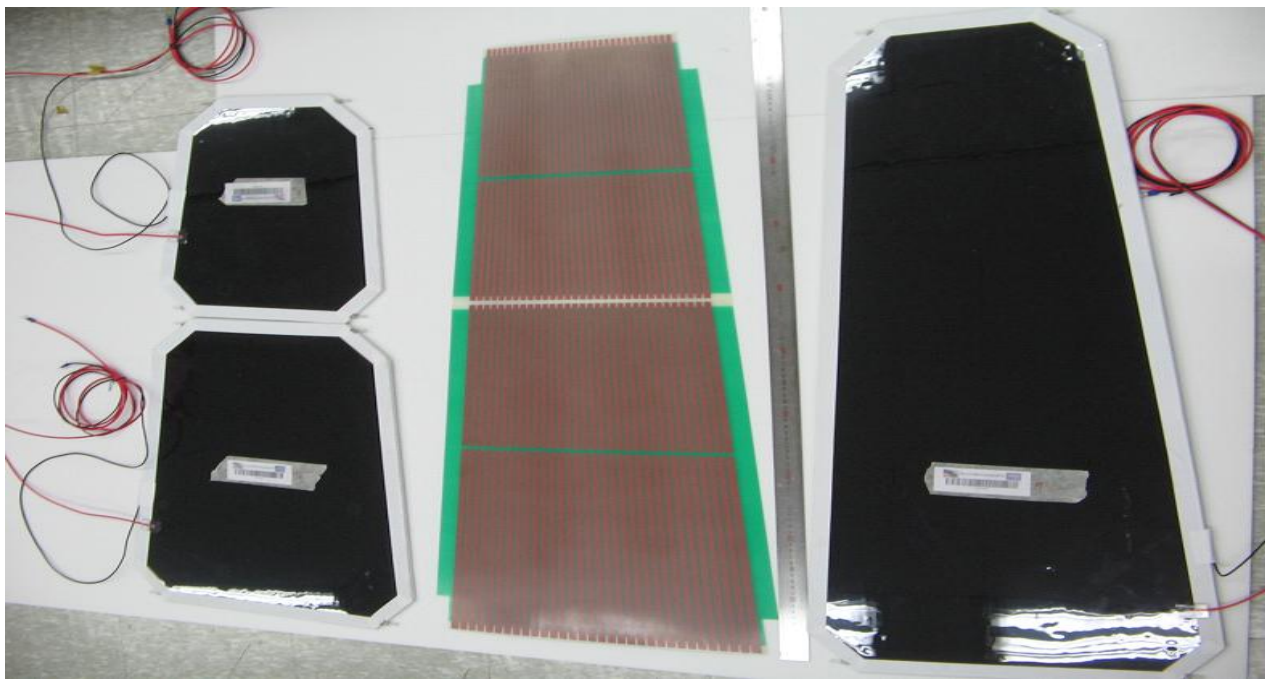


Tsinghua collaborate with Lyon IPNL for the GRPC project.

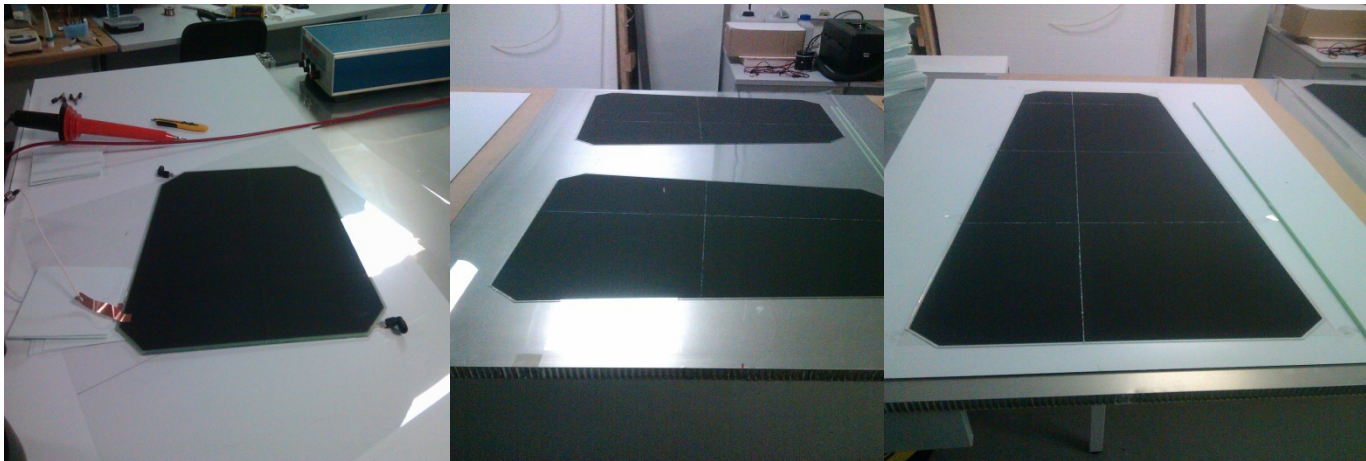
## Estimated cost of Muon system

Cost Estimate for Muon System		
Item	Sub-item	Estimated CORE Cost (MCHF 2013)
	DT minicrate electronics	3.4
	DT trigger electronics	2.2
	DT Controls	1.1
	DT minicrate installation	0.4
<b>Aging and Longevity</b>		<b>7</b>
	GEM chambers: ME1/1 + ME2/1	2.2
	GRPC Chambers: ME3/1 + ME4/1	1.6
	GEM Electronics	4.0
	GRPC Electronics	1.1
	Power Systems	2.0
	Services	0.6
	Installation	0.4
<b>Muon Stations <math>1.6 &lt;  \eta  &lt; 2.4</math></b>		<b>12</b>
	Gem Chambers: ME0	0.6
	Electronics	4.0
	Power System	1.0
	Services	0.5
	Installation	0.1
<b>Muon Taggins Station <math>2.2 &lt;  \eta  &lt; 4</math></b>		<b>6</b>
<b>Total</b>		<b>25</b>

Bakelite  
RPC



GRPC



A similar GRPC using standard glass plates smaller than  $30 \times 30 \text{ cm}^2$  were built. After validation, identical GRPC will be built using low-resistivity glass 32

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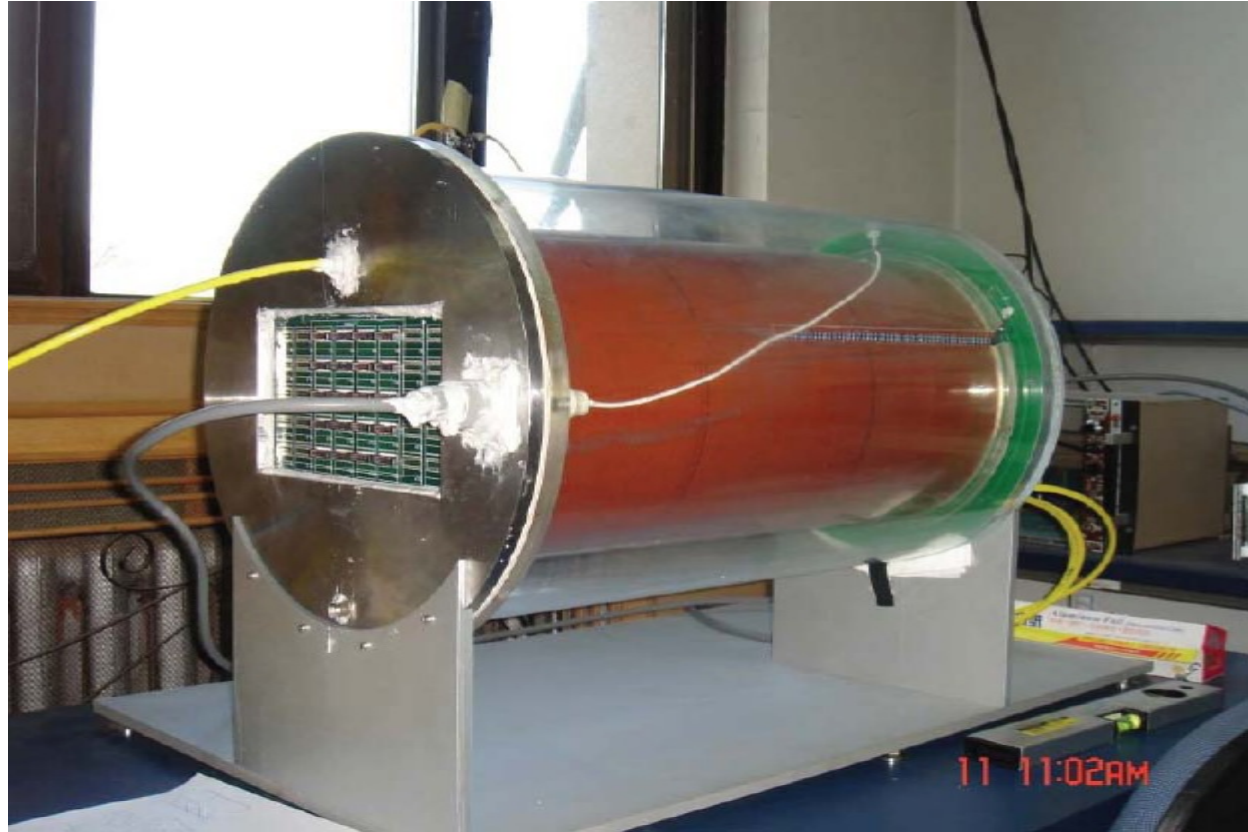
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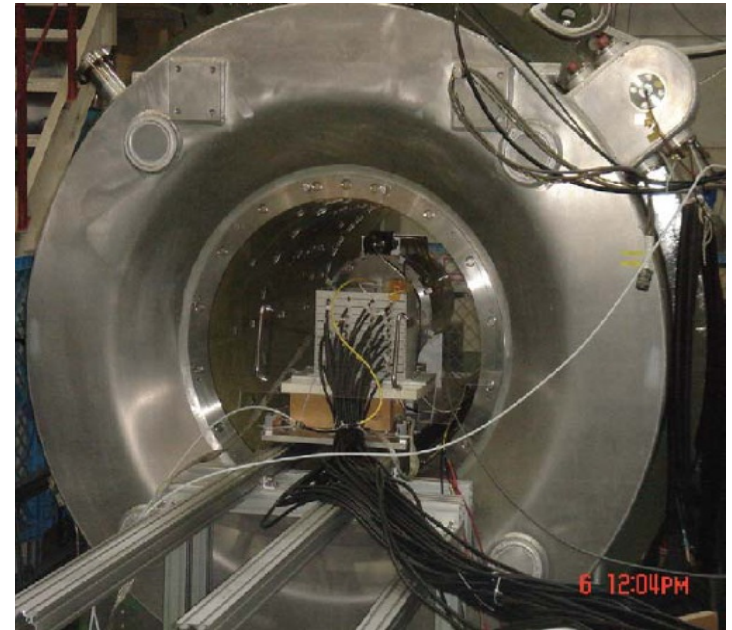
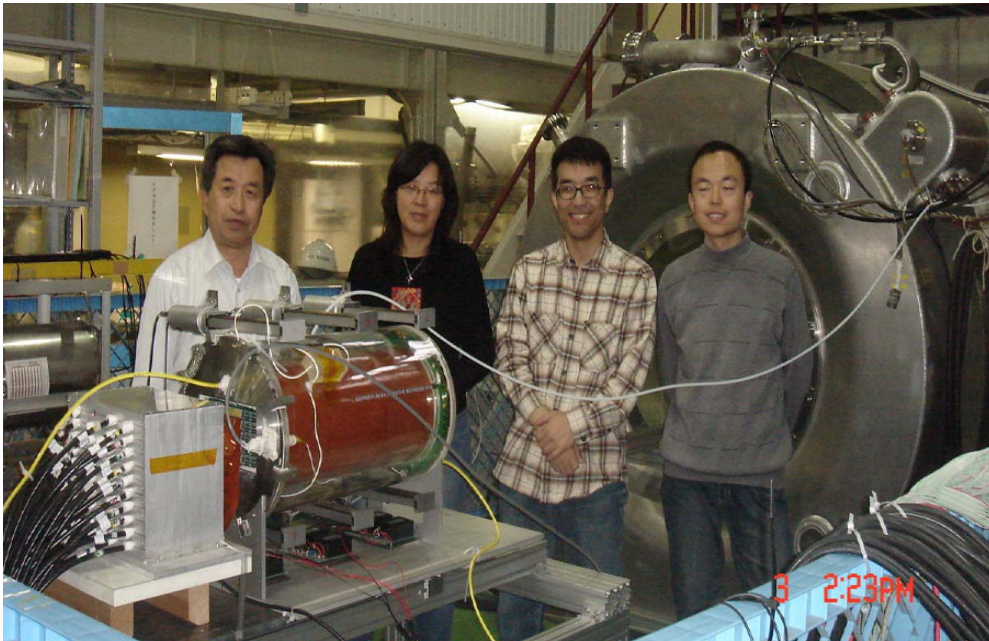


# TU-TPC prototype

- Readout pad size: 9.5 mm  $\times$  1.5 mm
- Pitch: 10 mm  $\times$  1.6 mm
- Staggered 10  $\times$  62 pads placed
- Only 10  $\times$  32 pads read out due to the limitation of electronic channel number



# Test @ KEK, Japan



- 1 Tesla
- Working Gas:
  - P10 ( $\text{Ar} : \text{CH}_4 = 90 : 10$ ),
  - ISO( $\text{Ar} : \text{CH}_4 : \text{iC}_4\text{H}_{10} = 96 : 3 : 1$ )

# Test Results

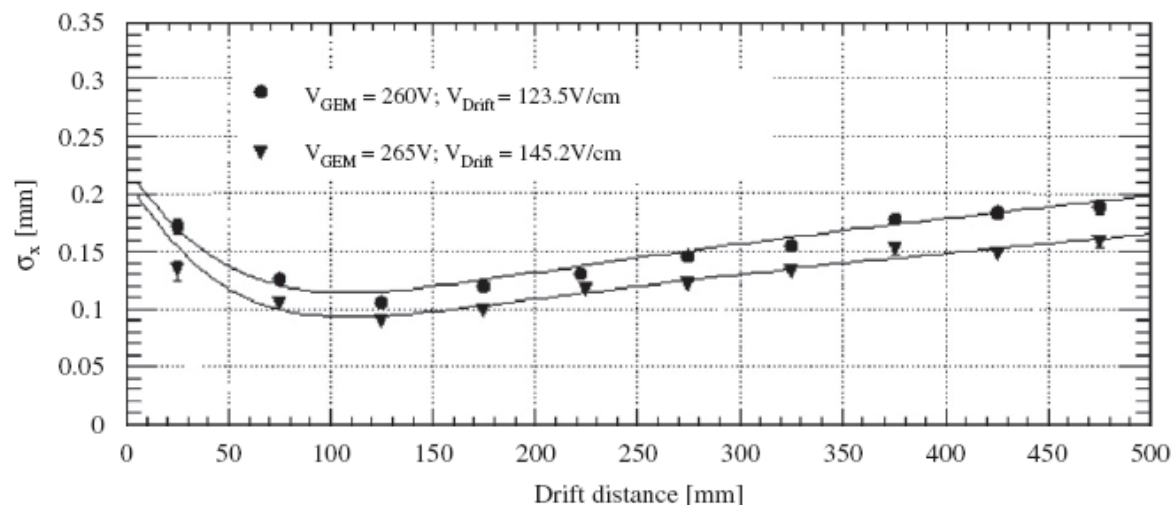


Fig. 6.  $x$ -Resolution for Ar-Iso-CF4 = 96.3–3.1–0.6 gas with  $B = 1\text{ T}$  under two different test conditions ( $\varphi < 2^\circ$ ,  $\theta < 10^\circ$ ).

Measurement points fit the analytical formula very well

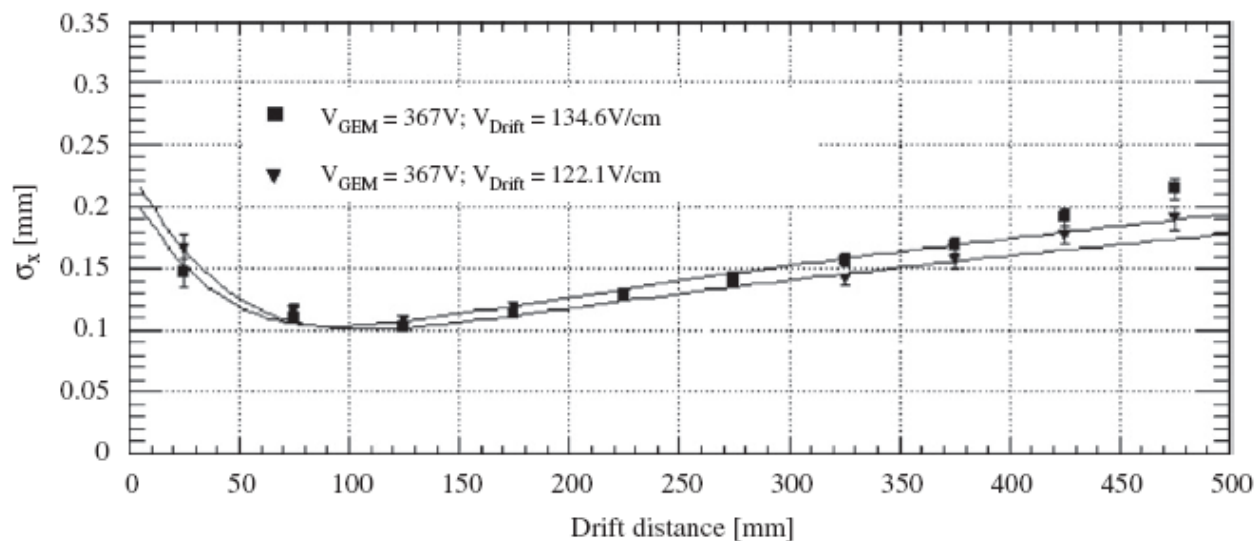


Fig. 7.  $x$ -Resolution for P10 gas with  $B = 1\text{ T}$  under two different test conditions ( $\varphi < 2^\circ$ ,  $\theta < 10^\circ$ ).

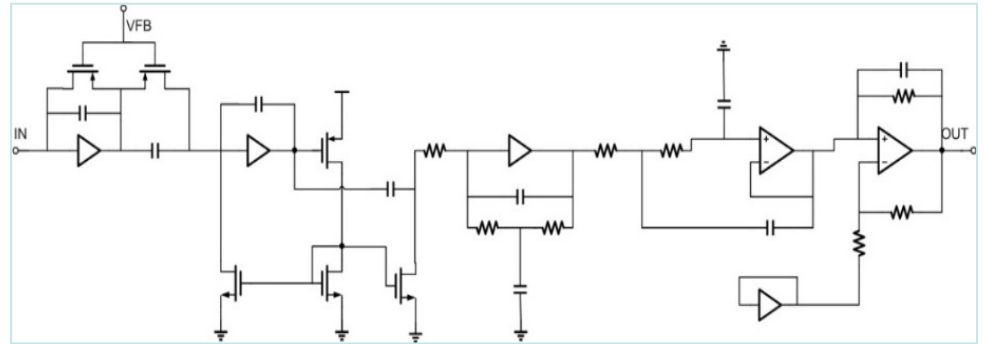
Resolution can be as good as  $100\text{ }\mu\text{m}@Z \approx 100\text{ mm}$

# CASA-GEM

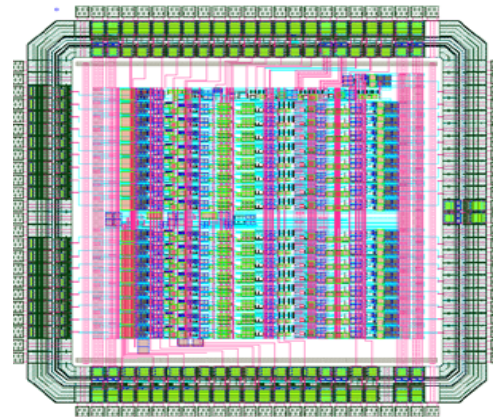
- CASAGEM: a multi-channel front-end ASIC for GEM detectors

## Specifications

Gain	2/4/20/40 mV/fC
Dynamic Range	Up to 1 pC
Shaper	CR-(RC) <sup>5</sup>
Peaking Time	100/200/300/400 ns
ENC	<1000 e
INL	<1%
Power Consumption	<10 mW
No. of Channels	16
Process	0.35 $\mu$ m CMOS



## Block Diagram

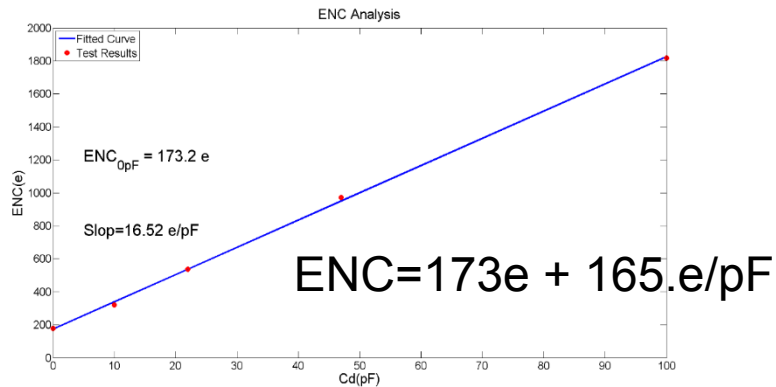


## Layout

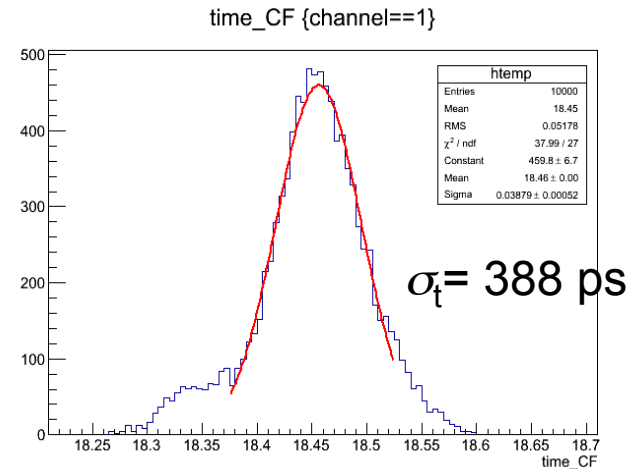


# Key Performances

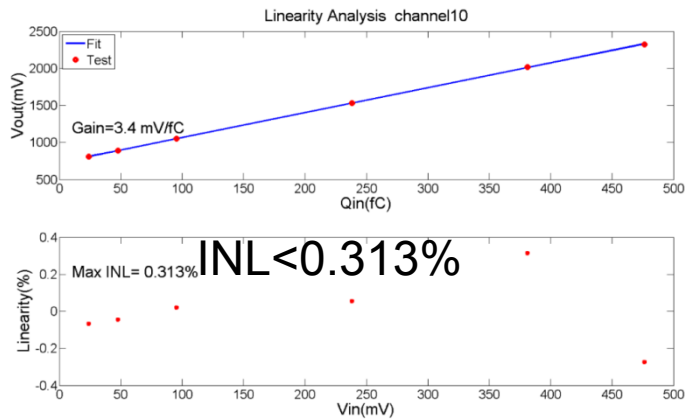
## ENC @ $t_p=400\text{ns}$



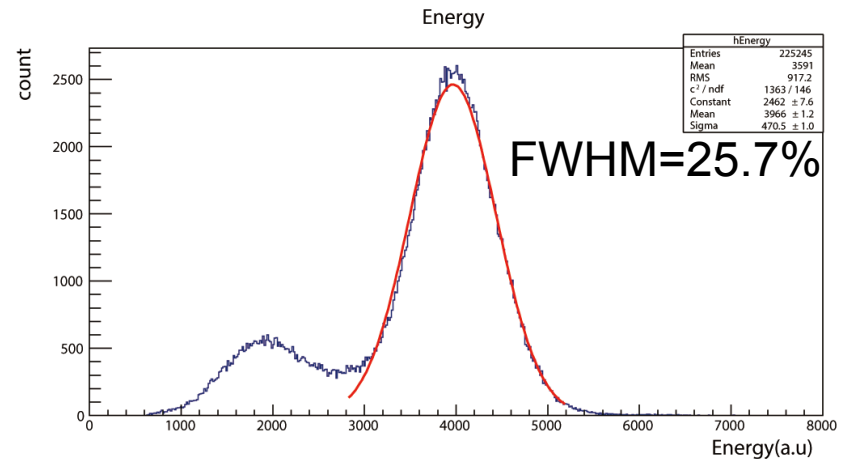
## Timing resolution @ $t_p = 400\text{ns}$



## INL @ $t_p=400\text{ns}$

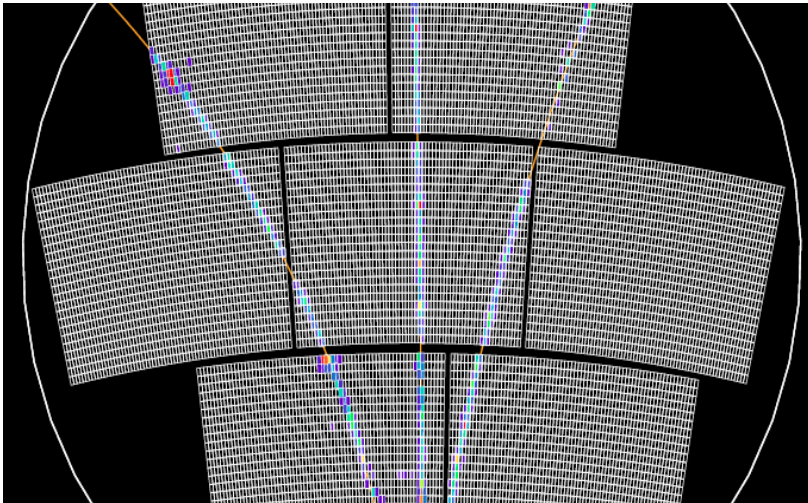


## Fe-55 Spectrum

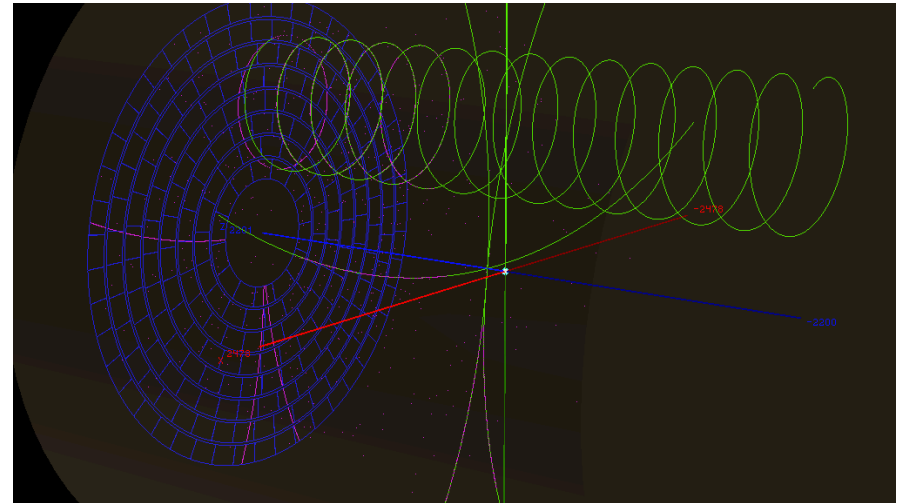


# Software development of TPC

- We join in the software development in the framework of LCTPC Collaboration, and especially work closely with the ILC group of IPNS (KEK).
- A Kalman filter based software package, KalTest, has been developed for track fitting in both uniform and non-uniform magnetic field.
- A track reconstruction program taking advantage of KalTest has been implemented in MarlinTPC, which is the software framework of LCTPC research. The program is used by the GEM and Micromegas group in their analysis of detector performance from 2010.



Micromegas beam test data on  
the Large Prototype, 2012

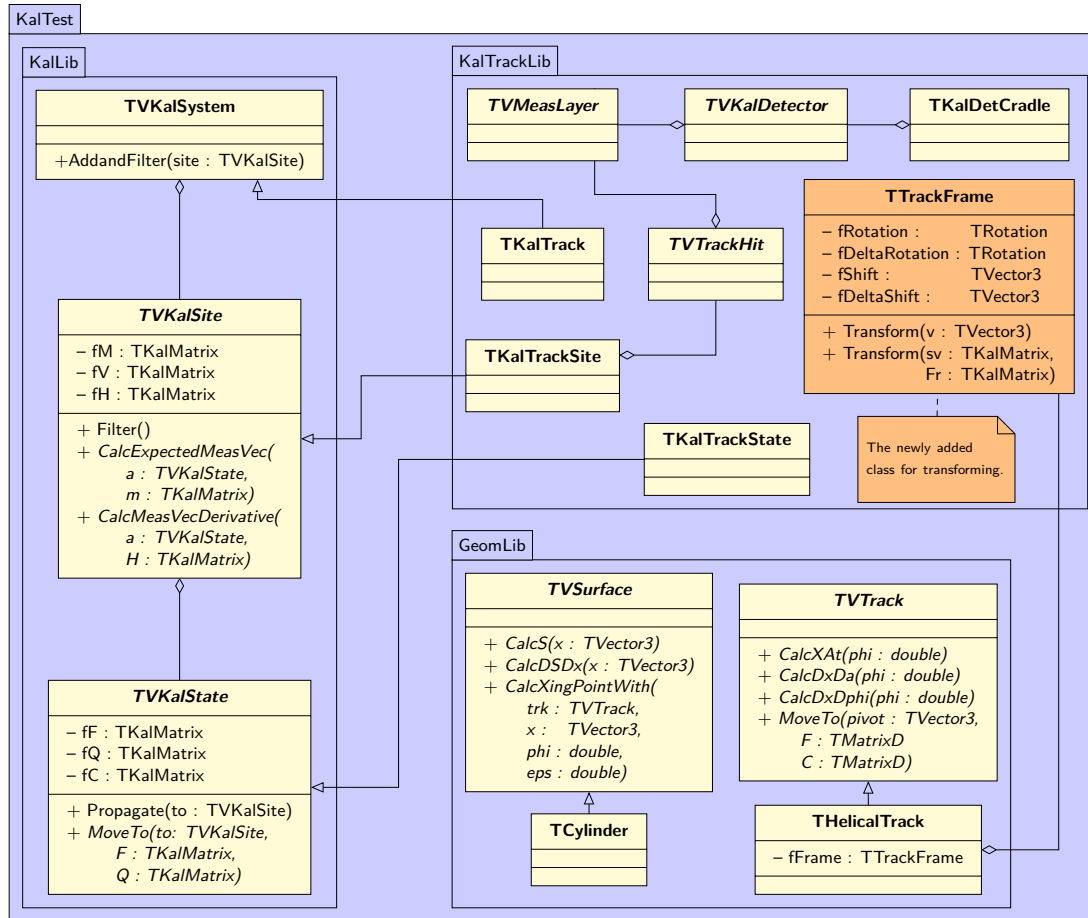


Tracks reconstructed by  
MarlinTPC for full endplate TPC



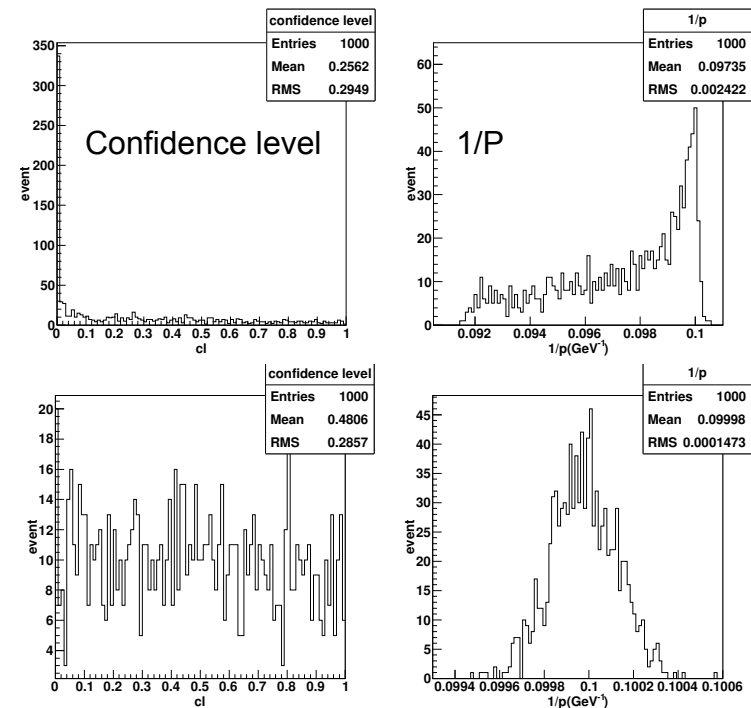
# The KalTest software package

## The structure of KalTest



More details of KalTest can be found at:  
<http://www-jlc.kek.jp/jlc/en/subg/soft/tracking>

The comparison of reconstructed results by the original Kaltest and recently updated version for non-uniform magnetic field:



Comp. Phys. Comm. (2013), <http://dx.doi.org/10.1016/j.cpc.2013.11.003>.

# HEP Projects @TU

- China Jing Ping Underground Lab
- LHCb (EX+EG), BES (EX+EG)
- RHIC/STAR(EX+DR), CBM(TH+DR)
- Daya Bay (EX+EG), SuperK (EX+EG). JUNO(EX+EG)
- ILC (TH+EX+AC+DT+DR), CLIC(AC+DG+DR), CEPC(TH+EX+DT)
- ATLAS (EX+EG?, in Chinese Cluster)  
CMS (DR, associate member)

TH: Theory group

AC: Accelerator group

EG: Electronics group

EX: Experiment group

DR: Detector group, MRPC

DT: Detector group, TPC

# HEP Projects @TU

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## CEPC-SppC Organization –

- Institutional Board:

chairman: GAO Yuanning (Tsinghua U); 1 rep. per institution

deputy chairman: GAO Jie (IHEP)

- Steering Committee:

chairman WANG Yifang (IHEP);

7 other members:

GAO Yuanning (Tsinghua), HAN Liang (USTC),

MAO Yajun (Peking U), JIN Shan (IHEP),

YANG Haijun (SJTU), HE Hong-jian (Tsinghua),

QIN Qing (IHEP)

## CEPC-SppC Organization –

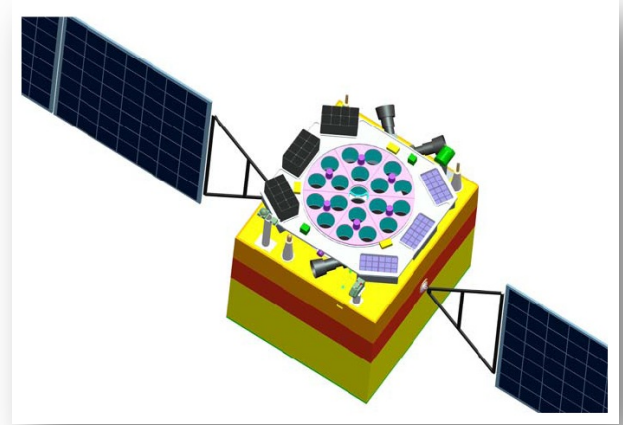
- Project directors: LOU Xinchou (IHEP), QIN Qing (IHEP)
- Working groups:
  - Theory (Conveners: HE Hong-jian, ZHU Shouhua)
  - Accelerator (Conveners: QIN Qing, GAO Jie)
  - Detector (Conveners: JIN Shan, GAO Yuanning)
- Established sub-groups (excellent subgroup conveners)
- Monthly Steering Committee + Conveners meetings
- 2-3 workshops per year

# High Energy Astrophysics & Space Astronomy

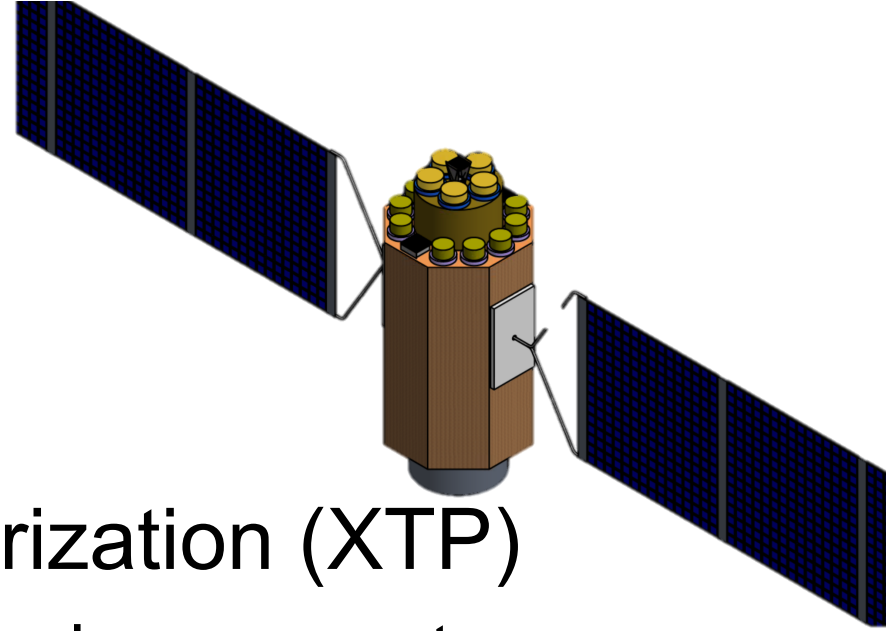
- Space astronomy (instrumentation)
  - as a collaborator
    - Hard X-ray Modulation Telescope (HXMT)
    - X-ray Timing and Polarization (XTP)
    - Einstein Probe (EP)
  - **as PI**
    - **LAMP (a small satellite project)**
- Black hole physics
  - Black hole binaries, ultraluminous X-ray sources
  - Active galactic nuclei



# HXMT



- Hard X-ray Modulation Telescope (HXMT)
- Developing the readout for the high energy detectors
  - Qualification model delivered
  - Flight model to be built soon
- Developing the data reduction software
- Leading the science definition team of HXMT

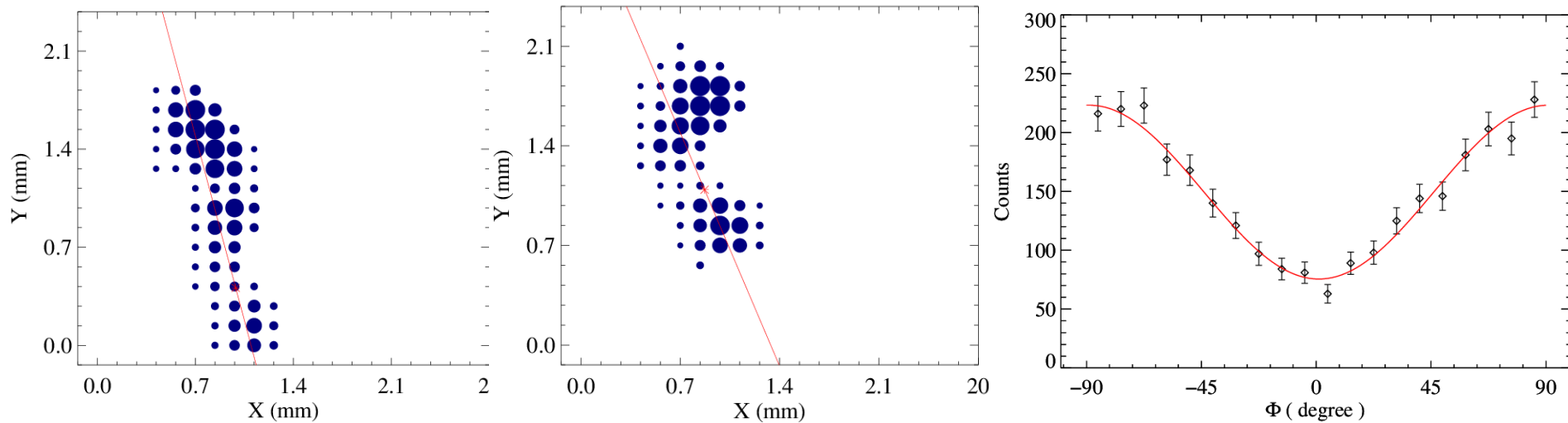
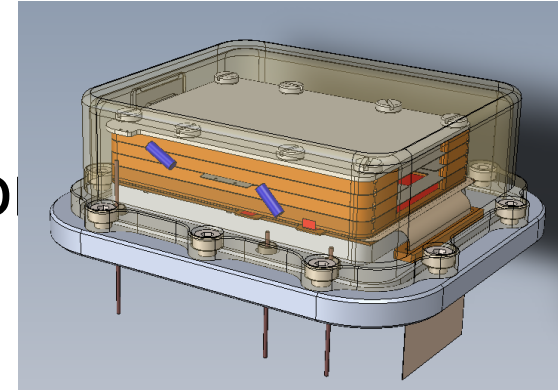


# XTP

- X-ray Timing and Polarization (XTP)
  - A observatory-class mission concept successive to HXMT
  - Currently in phase A/B study
- Developing the X-ray polarimeter
  - Gaseous photoelectric polarimeter
  - GEM + TPC readout

# A photoelectric X-ray polarimeter

- Measuring the emission direction of photoelectrons
- GEM + TPC readout, sealed proportional counter, lifetime 5-10 years
- A new version using micromegas is under construction in collaboration with

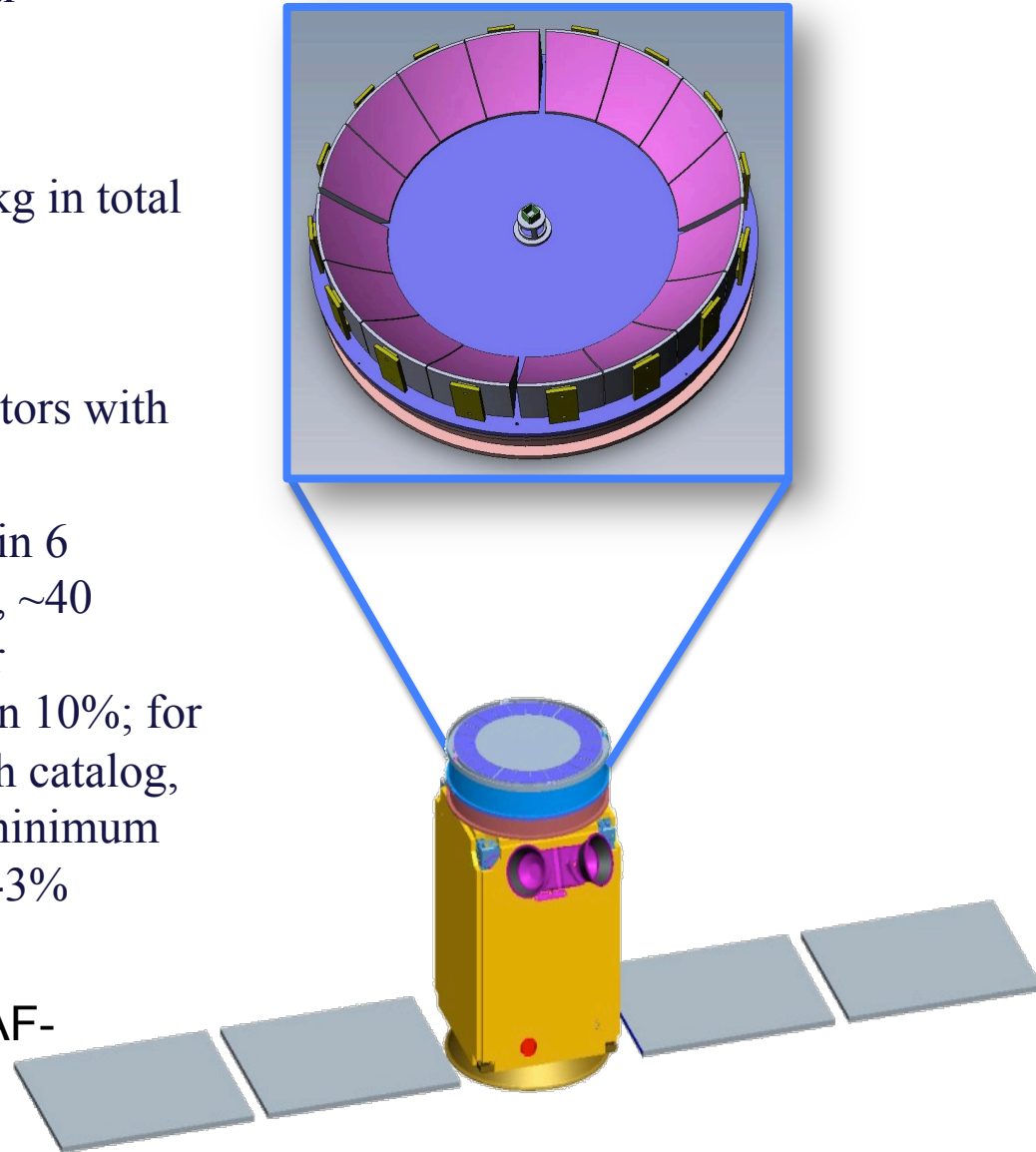


Measured 6 keV electron tracks and the modulation curve

# LAMP (Lightweight Asymmetry and Magnetism Probe)

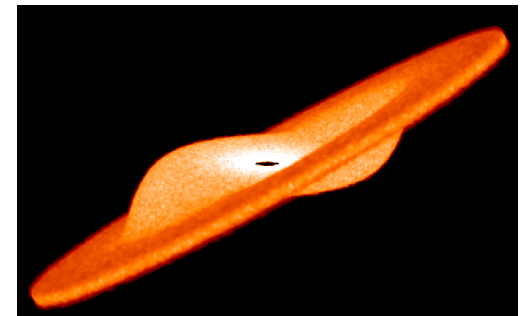
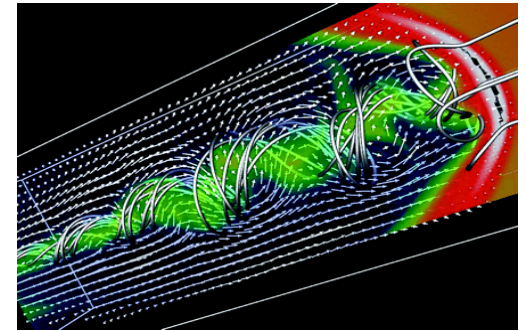
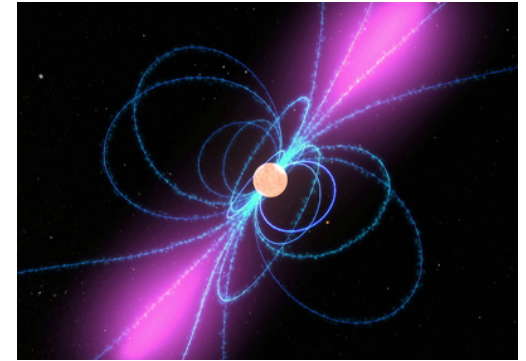
Optics	16 segments of paraboloidal multilayer-coated mirrors
Energy	250 eV; bandwidth 2.6 eV
Weight	< 35 kg for payload; ~100 kg in total
Collecting area	1300 cm <sup>2</sup>
Focal plane detector	Position sensitive gas detectors with ultrathin window
Sensitivity	Able to detect polarization in 6 pulsars, ~30 X-ray binaries, ~40 blazars, ~100 AGNs if their polarizations are higher than 10%; for the brightest sources in each catalog, the sensitivity in terms of minimum detectable polarization is 1-3%

Collaborators: Tsinghua U, Tongji U, Microsat, IAPS-Rome, INFN-Pisa, INAF-OAB



# Science with LAMP

- ✧ Measuring the magnetic field structure of pulsars and testing the vacuum polarization effect predicted by QED
- ✧ Capable of finding bare quark stars if they exist
- ✧ Probing the magnetic fields in relativistic jets: their role in jet formation, collimation, and acceleration
- ✧ Measuring the inner disk inclination: decoupling the black hole spin and disk inclination





# 清华大学高能物理研究中心

Center for High Energy Physics, Tsinghua University

## 导航 Contents:

中心简介 About TUHEP  
学术委员会 Committee  
中心成员 People  
研究方向 Research  
招聘信息 Employment  
发表文章 Publication  
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Rev.Part.Phys.  
Nobel Prize in Physics  
JSPS  
Geant4  
Geant4@in2p3

## 庆祝高能物理研究中心成立十周年! (2004-2014)

AFTER THE HIGGS DISCOVERY:  
WHERE IS FUNDAMENTAL PHYSICS GOING

### 希格斯粒子发现之后: 基础物理学向何处发展

和世界一流物理学家对话

FACE TO FACE DIALOGUE WITH WORLD LEADING PHYSICISTS



Moderator: Shing-Tung Yau (Harvard Univ. & Tsinghua Univ., USA, Fields Medalist)  
主持人: 丘成桐(美国哈佛大学 & 清华大学, 菲尔兹奖获得者)



## 新闻 News:

-->All Events

- 高能物理中心10周年系列学术活动(2): 2014年2月27日, 美国亚利桑那大学苏淑芳副教授访问清华大学高能物理研究中心, 并在刘卿楼报告厅为工物系和物理系师生作学术报告“探测暗物质: 上天, 入地, 看人间”。(报

## Highlights:

- Prof. Rolf-Dieter Heuer(Director-General of CERN) and Prof. Felicitas Pauss(Coordinator of External Relations of CERN) visit Tsinghua University
- TeV Working Group in China
- CCAST-Tsinghua School on Calorimetry for International Linear Collider
- 2008 Nobel Prize in Physics ( Report from ScienceNet )
- The Coming Revolutions in Particle Physics by Prof. Chris Quigg ( English , Chinese )
- ILC Physics Summary
- Large Hadron Collider (LHC) @ 2008
- Overview on IPMU by Hitoshi Murayama



# Mid-Long term plan (1)

- BESIII -> 202x  
LHCb upgrade 2018, 2019 -> 202y
  - \* Current members
    - Quarkonium production+Bc+pA
    - + Liming ZHANG (from Sept. 2014)
    - CCNU group
    - CP violation, rare decays
- 202xy->
  - \* ATLAS or CMS
  - \* ILC, CEPC...

# Mid-Long term plan (2)

- Underground lab
  - CJPL phase I ->  
Phase II 2015->
- Neutrino physics
  - Daya Bay -> 201x
  - SuperK ->
  - Juno -> 202x

Opportunities to combine the efforts?

# Summary

- HEP@TU is a typical example for Chinese Universities
- In last 10+ years, significant development in a tough environment
- Time to think about the future
- Welcome new members!

# Tsinghua University: A Brief History

- 1911 Founded as “Tsinghua XueTang” , a preparatory school
- 1925 University section established
- 1928 National Tsinghua University

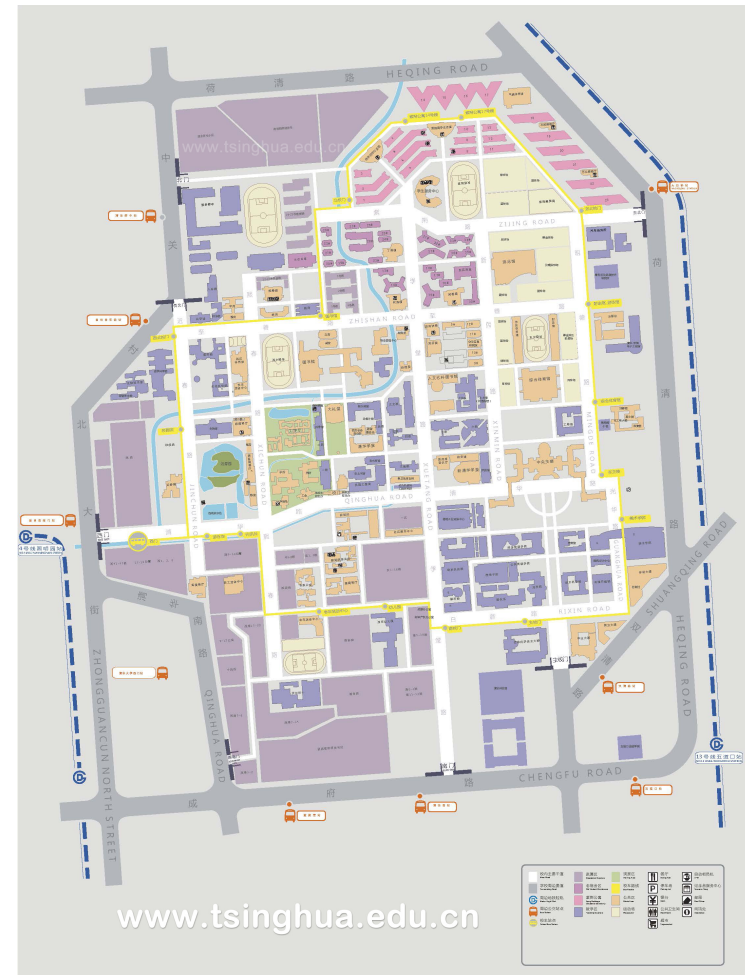


# Tsinghua University: A Brief History

- 1937 Moved to Kunming  
Nankai + Peking + Tsinghua  
= National Southwest Associate University
- 1946 Moved back to Beijing
- 1952 Became a Polytechnic University
- 1978 – Sciences, Economy, Law, etc

# Tsinghua University: Statistics

- **Schools: 16**
- **Departments: 56**
- **Faculty: 3133**
- **Undergraduate students:  
~15'000**
- **Graduate students:  
~16'000**





# Physics @TU

- 1926 Department of Physics established by Professor Ch'i-Sun Yeh, soon earned a reputation as one of the best Physics Departments in China



# Physics @TU

- In 1937, Tsinghua was forced to move from Beijing to Kunming, Yunnan Province, and was merged into “National Southwest Associate University” with Peking University and Nankai University. A great amount of outstanding scholars were educated in this Department during the World War II, such as T. D. Lee (Nobel Laureate), C. N. Yang (Nobel Laureate), Kun Huang, Jia-xian Deng, Guang-ya Zhu, *et al.*